Dennis R Sadler

Commercial RADIO OPERATOR'S QUESTION and ANSWER LICENSE GUIDE

FOR ELEMENT 3

INCLUDES

SAMPLE FCC TYPE PRACTICE EXAMS

Using MULTIPLE-CHOICE QUESTIONS

PREPARATION FOR RADIOTELEPHONE AND RADIOTELEGRAPH LICENSE EXAMINATIONS

AMECO

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Dennis R Sayle

COMMERCIAL RADIO OPERATOR'S LICENSE GUIDE – ELEMENT 3

by

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GUIDE — ELEMENT 3

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PREFACE

The AMECO Commercial Radio Operator's License Guide - Element 3, is part of a series of guides published by the Ameco Publishing Corp. for the purpose of preparing students for the Federal Communications Commission's Commercial Radio Operator's examinations.

As is the case with the other Ameco guides, this guide includes a sample FCC-type test. This sample test provides an added means of preparation for the actual FCC exam, and may serve as an accurate gauge of preparedness. The answers to the questions are in the back of the book. The questions duplicate the format of the FCC exam; most of them are of the multiple-choice type and cover the entire range of material that is covered by the FCC on their exam.

In addition to the other elements, the satisfactory completion of the Element 3 examination is necessary for the Radiotelephone 1st and 2nd Class Operator's licenses. The following are the requirements for the various classes of Commercial Radio Operator's licenses and permits issued by the Federal Communications Commission:

Radiotelephone 1st Class Operator's license - Elements 1, 2, 3, 4.
Radiotelephone 2nd Class Operator's license - Elements 1, 2, 3.
Radiotelephone 3rd Class Operator's permit - Elements 1, 2.
Restricted Radiotelephone permit - No written or oral examination.
Radiotelegraph 1st Class Operator's license - Elements 1, 2, 5, 6.
Radiotelegraph 2nd Class Operator's license - Elements 1, 2, 5, 6.
Radiotelegraph 3rd Class Operator's permit - Elements 1, 2, 5.
Aircraft Radiotelegraph Endorsement on 1st or 2nd Class license - Element 7.
Ship Radar Endorsement on Radiotelegraph or Radiotelephone 1st or 2nd Class license - Element 8.

The FCC examination for Element 3 consists of 100 multiple-choice questions, similar to the exam on Page 146. One percent (1%) credit is allowed for each question answered correctly. Seventy-five percent (75%) is the passing mark for the examination element.

The material presented in each answer should give the reader sufficient information to understand the answer and be prepared for the FCC exam. However, if the prospective radio operator requires additional information on the subject, a complete text entitled "Commercial Radio Operator Theory Course", Cat. No. 15-01, is recommended. See back cover. The numbers at the end of each question represent the chapter in the "Commercial Radio Operator Theory Course" where additional information concerning that particular question can be found.

Although this guide covers only Element 3 of the Commercial Radio Operator's examinations, the Ameco Publishing Corp. has published other guides covering Elements 1, 2, 4 and 9. License guides covering the requirements for the Radio Amateur Operator examinations have also been published. See back cover for listing of all Ameco guides.

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ELEMENT 3

ALTERNATING AND DIRECT CURRENT

Question 1. By what other expression may a "difference of potential" or "electromotive force" be described? 1.*

Answer. A "difference of potential" or "electromotive force" may be described by the following terms: voltage, emf, IR drop, fall of potential, difference of charge.

Q. 2. By what other expression may an "electric current flow" be described? 1.

A. Electric current flow may be described as a flow of electrons.

Q. 3. Explain the relationship between the physical structure of the atom and electrical current flow. 1.

A. An atom consists of electrons and protons. Some electrons can be displaced from some atoms. When these electrons, with their negative charges move from one atom to another, we say that there is an electric current flow. In other words, the flow of electrons is an electrical current flow.

Q. 4. With respect to electrons, what is the difference between conductors and non-conductors? 1.

A. A conductor has a large number of free electrons which are not bound tightly to their atoms. They move about freely and constitute the flow of electrons when the conductor is in an electrical circuit. A non-conductor's electrons are tightly bound to their atoms and will not leave their atoms to flow when an emf is applied.

Q. 5. What is the difference between electrical power and electrical energy? In what units is each expressed? 2.

A. Electrical energy is a certain amount of electrical work. Electrical power is the RATE of doing this work or work per unit of time. The unit of electrical energy is the joule. The unit of power is the watt. One watt is equal to one joule per second.

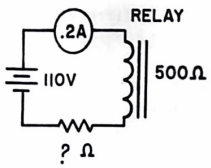
Q. 6. What is the relationship between impedance and admittance? Between resistance and conductance? 4, 1.

*See next-to-last paragraph in Preface.

A. Impedance (Z) is the reciprocal or opposite of admittance (Y) Resistance (R) is the reciprocal or opposite of conductance (G).

$$Z = \frac{1}{Y} \qquad Y = \frac{1}{Z} \qquad R = \frac{1}{G} \qquad G = \frac{1}{R}$$

Q. 7. A relay with a coil resistance of 500 ohms is designed to operate when 0.2 ampere flows through the coil. What value of resistance must be connected in series with the coil if it is to be energized by a 110 volt DC source? 2.



A. We must first determine the total amount of resistance in the circuit to produce .2 ampere.

$$R = \frac{E}{I} = \frac{110}{.2} = 550 \text{ ohms}$$

Since the coil has 500 ohms, the resistor should have 50 ohms.

Q. 8. Draw a circuit composed of a 12 volt battery with three resistors (10, 120 and 300 ohms respectively) arranged in a "pi" network. 2.

(a) What is the total current; the current through each resistor?
(b) What is the voltage across each resistor?
(c) What power is dissipated in each resistor; the total power dissipated by the circuit?

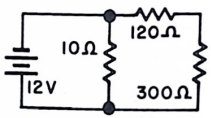


Figure 8. A series-parallel circuit.

A. The circuit is a series-parallel circuit. The 120 ohm resistor and the 300 ohm resistor are in series with each other. This combination is in parallel with the 10 ohm resistor.

(a) We can first find the current through the 10 ohm resistor by using Ohm's law:

$$I = \frac{E}{R} = \frac{12}{10} = 1.2 \text{ amps}$$

The current through the 300 ohm resistor and the 120 ohm resistor is the same since they are in series with

each other. The current through this branch is equal to the voltage across the branch divided by the total resistance of the branch.

$$I = \frac{E}{R} = \frac{12}{420} = .0286A$$

Thus the current through the 300 ohm resistor is .0286A and the current through the 120 ohm resistor is .0286A. The total current is the sum of the currents in the two parallel branches:

$$I_T = I_{10} + I_{300\ \&\ 120} = 1.20 + .0286 = 1.2286A$$

(b) the voltage across each resistor is equal to the product of the current through the resistor and the resistance of the resistor.

$$E_{10} = IR = 1.2 \times 10 = 12 \text{ V.}$$

$$E_{300} = IR = .0286 \times 300 = 8.58 \text{ V.}$$

$$E_{120} = IR = .0286 \times 120 = 3.43 \text{ V.}$$

(c) The power dissipated in each resistor is equal to the square of the current through the resistor multiplied by the product of its resistance.

$$P = I^2R$$

$$P_{10} = (1.2)^2 \times 10 = 1.44 \times 10 = 14.4 \text{ watts}$$

$$P_{300} = (.0286)^2 \times 300 = .00081796 \times 300 = .2454 \text{ W.}$$

$$P_{120} = (.0286)^2 \times 120 = .00081796 \times 120 = .098 \text{ W.}$$

The total power dissipated by the circuit is equal to the sum of the powers dissipated by each resistor.

$$P_T = P_{10} + P_{120} + P_{500}$$

$$P_T = 14.4 + .2454 + .098 = 14.7434W$$

Q. 9. Draw a circuit composed of a voltage source of 100 volts - 1000 cps, a 1 microfarad capacitor in series with the source, followed by a "T" network composed of a 2 millihenry inductor, a 100 ohm resistor and a 4 millihenry inductor. The load resistor is 200 ohms. 4. (material in answer is useful but not required on FCC exam).

(a) What is the total current; the current through each circuit element?

(b) What is the voltage across each circuit element?

(c) What "apparent" power is being consumed by the circuit?

(d) What real or actual power is being consumed by the circuit; by the 200 ohms resistor?

A. The circuit in this question appears in Figure 9A. It can be drawn as shown in Figure 9B. Z1 is the series impedance of C1 and

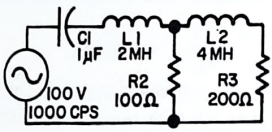


Fig. 9A. A series-parallel AC circuit.

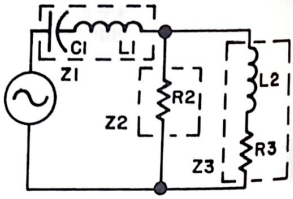


Fig. 9B. Same circuit redrawn

L1 and is calculated in the following manner:

$$Z1 = X_{L1} + X_{C1} = j2\pi fL1 + \frac{1}{j2\pi fC1}$$

since $\frac{1}{j} = -j$ we can substitute in the above equation.

$$j2\pi fL1 - j\frac{1}{2\pi fC1} = j\left(2\pi fL1 - \frac{1}{2\pi fC1}\right)$$

$$Z1 = j\left[(6.28)(1000)(2 \times 10^{-3}) - \frac{1}{(6.28)(1000)(1 \times 10^{-6})}\right]$$

$Z1 = j\,(12.56 - 159.2)$ $\qquad$ $Z1 = -j\ 147$ ohms

Z2 is the impedance of resistor R2:

$Z2 = R2 = 100 + j0$ $\qquad$ $Z2 = 100 + j0$ ohms

When we substitute Z2 below, we can leave out the j0. The j0 indicates that the reactive component is zero and only the resistance is present.

Z3 is the series impedance of L2 and R3 and is calculated as follows:

$Z3 = R3 + j2\pi fL3$

$Z3 = 200 + j(6.28)(1000)(4 \times 10^{-3})$

$Z3 = 200 + j25.12$ ohms

The parallel impedances can be replaced by an equivalent impedance Z_e as shown in Figure 9C:

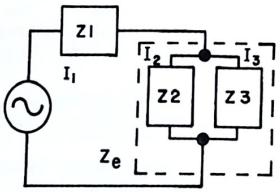


Figure 9C. The equivalent circuit.

Z_e is computed in the following manner:

$$Z_e = \frac{(Z2)\,(Z3)}{Z2 + Z3} = \frac{(100)\,(200 + j25.12)}{100 + 200 + j25.12}$$

$$Z_e = \frac{(100)\,(200 + j25.12)}{300 + j25.12} = \frac{200 + j25.12}{3 + j0.2512}$$

Z_e is most readily simplified by converting both the numerator and denominator to polar form:

$$Z_e = \frac{Z_n}{Z_d} = \frac{Z_n \angle\theta_n}{Z_d \angle\theta_d}$$

Where: $Z_n = 200 + j25.12$ and $Z_d = 3 + j0.2512$

By using proper trigonometry, we arrive at the following:

$$Z_e = \frac{Z_n}{Z_d} = \frac{201.57 \angle 7.17^\circ}{3.01 \angle 4.8^\circ} = \frac{201.57}{3.01} \angle 7.17^\circ - 4.8^\circ$$

$Z_e = 66.97 \angle 2.37^\circ$ ohms. (This equals 66.91+j277 in rectangular form)

We add Z1 and Z_e to get Z_t:

$Z_t = (-j147 + (66.91 + j2.77) = 66.91 - j144.23$

By converting Z_t to polar form and using proper trigonometry we find that:

$$Z_t = \frac{66.91}{\cos(-65.1^\circ)} = \frac{66.91}{0.421} = 158.92 \text{ ohms or, indicating}$$

the angle, $Z_t = 158.92 \angle -65.1^\circ$ ohms.

The total current can now be found by using Ohm's law:

$$I_t = \frac{V}{Z_t} = \frac{100 \angle 0^\circ}{158.92 \angle -65.1^\circ} = \frac{100}{158.92} \angle 0^\circ - (-65.1^\circ)$$

$I_t = 0.630 \angle 65.1^\circ$ ampere

The current through L1 and C1 is the same as the total current since the total current must pass through these elements.

To determine I_2 and I_3 we must find the voltage across Z_e. It is the same as the voltage across Z2 and Z3.

We must use Ohm's law to find the voltage across Ze (V_e).

$V_e = I_t \times Z_e = (0.630 \angle 65.1^\circ)(66.97 \angle 2.37^\circ)$

$V_e = (0.630)(66.97) \angle 65.1^\circ + 2.37^\circ = 42.19 \angle 67.47^\circ$ volts

Then:

$$I_2 = \frac{V_e}{Z2} = \frac{42.19 \angle 67.47^\circ}{100 + j^\circ} = \frac{42.19 \angle 67.47^\circ}{100 \angle 0^\circ}$$

$I_2 = 0.4219 \quad 67.47^\circ$ ampere

$$I_3 = \frac{Ve}{Z3} = \frac{42.19 \angle 67.47^\circ}{201.57 \angle 7.17^\circ} = 0.209 \angle 60.3^\circ \text{ ampere}$$

I_3 is the current flowing through L2 and R3.

The voltage across each element is found by multiplying the current through each element by the impedance of the element (Ohm's Law).

The voltage across C1 is:

$$V_{C1} = I_t Z_{C1} = 0.630 \times \frac{1}{6.28 \times 1000 \times 1 \times 10^{-6}}$$

$$= 0.630 \times 159.2 = 100.29 \text{ volts}$$

The voltage across L1 is:

$$V_{L1} = I_t Z_{L1} = 0.630 \times 6.28 \times 1000 \times 2 \times 10^{-3} = 7.91 \text{ volts}$$

The voltage across R2 is:

$$V_{R2} = I_2 R2 = .42 \times 100 = 42 \text{ volts}$$

The voltage across L2 is:

$$V_{L2} = I_3 Z_{L2} = 0.209 \times 6.28 \times 1000 \times 4 \times 10^{-3} = 5.25 \text{ volts}$$

The voltage across R3 is:

$$V_{R3} = I_3 R2 = .209 \times 200 = 41.8 \text{ volts}$$

The apparent power is equal to the source voltage multiplied by the total current, I_t.

$$P \text{ app.} = 100 \times .63 = 63 \text{ watts}$$

The real or true power can be found by adding the powers dissipated by each resistor. The inductors and capacitors do not dissipate or "use" power. They store energy.

$$P_{true} = P_{R2} + P_{R3}$$

$$P_{R2} = I_{R2}^2 \; R2 = (.42)^2 \times 100 = 17.640 \text{ watts}$$

$$P_{R3} = I_{R3}^2 \; R3 = (.209)^2 \times 200 = 8.736 \text{ watts}$$

Total True Power = P_{true} = 17.64 + 8.736 = 26.376 watts

Q. 10. What is the relationship between wire size and resistance of the wire? 1.

A. The resistance is inversely proportional to the cross-sectional area. Example: If the cross-sectional area is doubled, the resistance is halved; if the cross-sectional or end area is tripled, the resistance is cut to 1/3 of its original value.

Q. 11. What is "skin effect"? How does it affect the resistance of conductors at the higher radio frequencies? 4.

A. "Skin effect" is the term used to denote the tendency of radio frequency currents to flow on, or near the surface of a conductor, rather than throughout the entire area. This condition exists because there are more magnetic lines of force cutting the center of the conductor than cutting the surface. There is less induced counter-emf or opposition at the surface than at the center. The resistance of the conductor is greater at higher frequencies due to skin effect than at the lower frequencies.

Q. 12. Why is impedance matching between electrical devices an important factor? Is it always to be desired? Can it always be attained in practice? 4, 8.

A. Impedance matching between electrical devices is important where maximum efficiency of energy transfer is needed. It is especially important in circuits handling appreciable power.

Impedance matching is not always desired. Some examples of intentional mismatching are as follows: to reduce power transfer efficiency, to control amplifier stability and to attain improved noise figure in receiver input circuits. A common example of intentional mismatch is in public address systems where a constant voltage line is used. The power taken from this line by any individual speaker is controlled by the selection of a tap on the line to speaker transformer. The speaker is not matched to the line. Therefore, it does not use all the energy in the line due to the level of mismatch. Exact impedance matching is often closely approached, seldom attained.

Q. 13. A loudspeaker with an impedance of 4 ohms is working in a plate circuit which has an impedance of 4000 ohms. What is the impedance ratio of an output transformer used to match the plate circuit to the speaker? What is the turns ratio? 9.

A. The impedance ratio of the output transformer would simply be $\frac{4000 \text{ ohms}}{4 \text{ ohms}}$ or 1000 to 1. The turns ratio would be the square root of the impedance ratio, namely $\sqrt{\frac{1000}{1}}$ or 31.6 to 1.

Q. 14. Compare some properties of electrostatic and electromagnetic fields. 1, 3.

A. The most elementary laboratory demonstrations of electrostatic and electromagnetic fields show some similarities and differences very plainly.

If a magnet is brought close to small pieces of iron, they will be attracted to the magnet and held there by the magnetic field. Similarly, if a piece of good electrical insulating material such as hard rubber, amber, polystyrene, etc., is rubbed with a suitable material, such as silk, the insulating material will accumulate a considerable electrostatic charge. If the charged insulator is brought close to some small pieces of good insulating material, such as paper, threads

of synthetic fibers, polystyrene drillings, etc., the small pieces will be attracted to the charged insulator and held there by the electrostatic field.

The magnet cannot attract the non-magnetic paper, threads, etc. The charged insulator cannot attract the magnetic iron pieces. A magnet cannot attract many metals, such as copper, silver, zinc, aluminum, lead, etc., as they are non-magnetic.

When a conductor (a wire) is moved in a magnetic field, a potential difference will be produced between the ends of the wire. Also, if there is not relative motion but the magnetic field strength varies, a potential difference will be produced between the ends of the wire. Electrostatic fields are used principally for electrical energy storage in capacitors. This applies equally to filter, bypass and resonating capacitors. Electrostatic charges outside of any equipment must also be considered. Lightning, rain and snow static and automobile wheel static are familiar electrostatic phenomena.

Q. 15. In what way are electrical properties of common circuit elements effected by electromagnetic fields? Are interstage connecting leads susceptible to these fields? 3, 13.

A. Electromagnetic fields produced by power transformers, filter chokes, wires carrying considerable alternating current, or motors, can act as the primary of a transformer. This can induce unwanted currents in such elements as audio transformers, wiring in low level amplifier stages, phonograph pickups and microphones. This is a common source of hum. When a cathode ray tube or other electron beam deflection tube is placed in such a field, AC or DC, it will be disturbed and deflection of the beam by the external field will occur. Interstage connecting leads are very susceptible to electromagnetic fields, not only at power frequencies, but also at signal and spurious frequencies. Shielding and position of such leads are important.

Q. 16. Which factors determine the amplitude of the emf induced in a conductor which is cutting magnetic lines of force? 3.

A. The amplitude of the emf induced in a conductor which is cutting magnetic lines of force depends on the following factors:

(1) strength of the magnetic field - the more the magnetic lines of force, the greater is the induced emf.

(2) speed of the moving conductor - the faster the movement of the conductor, the greater the induced emf.

(3) number of turns of wire - the more the turns, the greater the number of lines of force being cut, hence the greater is the induced emf.

(4) relative angle of the conductor to the magnetic lines of force - the greater the angle (up to a maximum of 90 degrees) the more lines of force are cut per second, hence the greater the amplitude of the induced emf. A maximum

voltage is induced when the conductor is moving perpendicular to the magnetic lines of force.

Q. 17. Define the term "reluctance". 3.

A. Reluctance is the property of a material that opposes the creation of magnetic lines of force. It is the magnetic equivalent of the resistance that opposes current flow in a circuit. It is equal to the magnetomotive force divided by the magnetic flux.

Q. 18. In what way does an inductance affect the voltage-current phase relationship of a circuit? Why is the phase of a circuit important? 4.

A. The current in an inductive circuit will lag the applied voltage. If there is no resistance (only inductance) the current will lag the voltage by 90^{o}. As we add resistance, the angle drops. If the inductive reactance is equal to the resistance, the current will lag the voltage by 45^{o}. As the resistance predominates over the inductive reactance, the angle of lag continues to drop. The angle of lag is 0 when the circuit is only resistive.

Voltage-current phase relations are important because the power factor of a circuit is dependent on the phase angle between the voltage and the current. When the voltage and current are in phase (0^{o} phase angle) the power factor is unity and the power is maximum. When the voltage and current are 90^{o} out of phase, the power factor is zero and the power is zero.

Q. 19. Draw two cycles of a sine-wave on a graph of amplitude versus time. Assume a frequency of 5 Mcs. 17, 4, 9.

(a) what would be the wave length of one cycle in meters; in centimeters?

(b) how many degrees does one cycle represent?

(c) how much time would it take for the wave to "rotate" 45^{o}; 90^{o}; 2800^{o}?

(d) if there were a second harmonic of this frequency, how many cycles thereof would be represented on this graph?

(e) on the same graph draw two cycles of another sine-wave leading the first by 45^{o}.

(f) what would be the velocity of this wave or any other electromagnetic wave in free space.

A. (a1) 60 meters. We arrive at this by using the formula for wavelength:

$$\lambda = \frac{300}{f} = \frac{300}{5} = 60$$

Where λ is wavelength in meters and f is frequency in Mc.

(a2) 6000 centimeters. To convert meters to centimeters, we multiply by 100 since there are 100 centimeters in 1 meter.

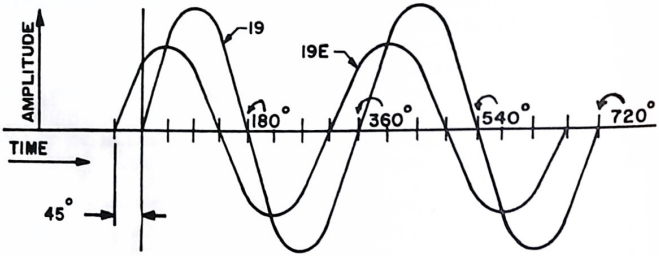


Figure 19. Two sine waves 45° apart.

(b) 360°. There are 360° in a complete cycle.

(c) the time in microseconds (one millionth of a second (symbol ms)) for a complete sine-wave (360°) is found by using the formula:

$$\text{time (ms)} = \frac{1}{\text{freq. in Mc.}}$$

Therefore, it would take 1/5 or .2 ms. for 360°. To find the time it would take for less than 360°, multiply the time for 360° by the fraction $\frac{\text{no. of degrees}}{360^\circ}$

(c1) to find the time it takes for 45°:

$$.2 \text{ ms} \times \frac{45^\circ}{360^\circ} = .2 \times .125 = .025 \text{ ms.}$$

(c2) to find the time it takes for 90°:

$$.2 \text{ ms} \times \frac{90^\circ}{360^\circ} = .2 \times .25 = .05 \text{ ms.}$$

(c3) to find the time it takes for 280°:

$$.2 \text{ ms} \times \frac{280^\circ}{360^\circ} = .2 \times .777 = 0.155 \text{ ms.}$$

(d) 4 cycles. The second harmonic is twice the frequency of the original signal.

(e) this second sign wave is represented by 19E on the above graph.

(f) 300, 000, 000 meters per second.

Q. 20. Explain how to determine the sum of two equal vector quantities having the same reference point but whose directions are 90° apart; 0° apart; 180° apart? How does this pertain to electrical currents or voltages? 4.

A. (a) If they are 90° apart, we multiply one of the vector quantities by 1.414 to arrive at the sum.

(b) If they are 0° apart, we merely add the two quantities.

(c) If they are 180° apart, we subtract the one quantity from the other. Since they are equal, the sum will be zero.

In electrical circuits, the voltages or currents can be in

phase (0^o) with each other, out of phase (not 0^o) with each other or completely opposite (180^o) in polarity.

Q. 21. Explain how the values of resistance and capacitance in an RC network affect its time constant. How would the output waveform be affected by the frequency of the input in an RC network? 4,13

A. The product of the resistance in ohms and the capacitance in farads is the Time Constant in seconds. T = RC. An RC network consisting of a resistance as the series element and the output shunted by the capacitance is a low pass filter or integrator. A sine-wave will pass through such a circuit with no change in waveform. It will have a loss of amplitude and phase shift which will increase with frequency. A complex wave will pass through with a greater attenuation of its high frequency components than its low frequency components; therefore, its waveform will be smoothed. With a long enough time constant, no AC would be passed.

When the R and C components are transposed (the capacitance is the series element and the output is shunted by the resistance) a differentiator or high pass filter is obtained. This will have opposite frequency characteristics, namely, the loss is reduced as the frequency is increased. The low frequency components of a complex wave are attenuated more than the high. Therefore, the high frequency components of the waveform will be accentuated.

Q. 22. Explain how the values of resistance and inductance in an RL network affect its time constant. 4.

A. The time constant T, in seconds, of an RL circuit is equal to the inductance in henrys divided by the resistance in ohms. $T = \frac{L.}{R}$

When a resistor, inductor and battery are connected in series, the current will start at a low value when the circuit is closed, attain 63.2% of maximum value at time T, following an exponential curve until the steady state maximum current is reached.

The RL current and the RC voltage follow the same exponential curve.

Q. 23. Explain the theory of molecular alignment as it affects magnetic properties of materials. 3.

A. When a piece of soft iron is magnetized, the molecules, each a tiny permanent magnet, will turn in the direction of the magnetic field and the material will become a magnet. When the magnetizing force is removed, the molecules will return to their original positions and the soft iron will no longer be a magnet.

In a material that can be permanently magnetized, the molecules will hold their new position, aligned in the direction of the field that was applied, adding the strength of the field of an individual molecule to all the others. This piece of material is now a permanent magnet.

Q. 24. What is the relationship between the inductance of a coil and the number of turns of wire in the coil; the permeability of the core material used? 4.

A. The inductance of a coil is directly proportional to the square of the number of turns.

Adding an iron core to an inductance increases the permeability of the core and, therefore, increases the inductance.

Q. 25. What factors influence the direction of magnetic lines of force produced by an electromagnet? 3.

A. The direction of the current flow and the direction of the windings determine the direction of the magnetic lines of force of an electromagnet.

Q. 26. Explain how self and mutual inductance produce transformer action. 4.

A. When an alternating current flows through a coil, the varying magnetic field around each turn cuts itself and the adjacent turns, inducing a voltage in the coil with the polarity opposite to the applied voltage. This voltage is called a counter-EMF or back EMF. This effect is called self-induction. If a second coil is placed in close proximity to the first coil, the varying magnetic field also cuts the turns of the second coil, inducing a current in it. The current in the second coil will also induce a current in the first coil. The reaction between the coupled coils is called mutual inductance. An assembly of two coils, inductively coupled, is called a transformer.

Q. 27. What does coefficient of coupling mean? 4.

A. The degree of coupling between a pair of inductors is expressed as the coefficient of coupling. This is the ratio of actual mutual inductance to the maximum possible mutual inductance.

Q. 28. How does the capacitance of a capacitor vary with area of plates; spacing between plates; dielectric material between plates? 4

A. The capacitance of a capacitor will vary in direct proportion to the area of the plates; the greater the plate area, the more the capacitance and vice versa. The capacity will vary inversely with the spacing between the plates - the greater the spacing, the less the capacity and vice versa. The capacity will vary in direct proportion to the dielectric constant of the material between the plates; the greater the dielectric constant, the greater the capacity and vice versa.

Q. 29. Assuming the voltage on a capacitor is at or below the maximum allowable value, does the value of the capacitor have any relationship to the amount of charge it can store? What relationship does this storage of charges have to the total capacitance of two or more capacitors in series; in parallel? 4.

A. Yes. The amount of charge a capacitor can store is equal to the product of the capacity and the voltage. $Q = CE$

Where "Q" is the amount of charge, "C" is the capacity and "E" is the voltage.

If we have two capacitors in series, the total capacity is reduced and its stored charge is smaller. If we add two capacitors in parallel, the total capacity is larger and the amount of charge stored is greater.

Q. 30. How should electrolytic capacitors be connected in a circuit in relation to polarity? Which type of low leakage capacitor is used most often in transmitters? 4, 7.

A. Electrolytic capacitors must always be connected with the positive terminal of the capacitor to the positive side of the circuit and the negative terminal of the capacitor to the negative side of the circuit. Oil filled paper dielectric capacitors are generally used in transmitter power supplies because of their low leakage. Ceramic and mica capacitors are used in other parts of the transmitter.

Q. 31. A certain power company charges 7¢ per kilowatt-hour. How much would it cost to operate three 120 volt lamp bulbs, connected in parallel, each having an internal resistance of 100 ohms, for 24 hours? 2.

A. $0.72576. First we must find the power consumed by each bulb by using one of the power formulas:

$$P = \frac{E^2}{R} = \frac{(120)^2}{100} = \frac{14400}{100} = 144 \text{ watts.}$$

Three bulbs will therefore consume 432 watts. We multiply this by 24 hours to arrive at the watt-hours. 432 x 24 = 10368 watt-hours. We divide this by 1000 to give us the kilowatt-hours consumed; = 10.368 kilowatt-hours. We then multiply this by .07 per kilowatt hour to obtain the total cost. 10.368 x .07 = $0.72576.

Q. 32. The output of an amplifier stage having a voltage gain of 30 db. is 25 volts. What is the input voltage level? 11.

A. The formula for the voltage gain of an amplifier in terms of decibels (db) is:

$$\text{db gain} = 20 \log \frac{E \text{ output}}{E \text{ input}}$$

We then substitute the given elements:

$$30 = 20 \log \frac{25}{E \text{ input}}, \quad \frac{30}{20} = \log \frac{25}{E \text{ input}}, \quad 1.5 = \log \frac{25}{E \text{ input}}$$

We go to the logarithmic table and find that 1.5 is equal to the log 31.6. Therefore:

$$\frac{25}{\text{input voltage}} = 31.6 \text{ or input voltage} = \frac{25}{31.6} = .79 \text{ volts.}$$

The formula for the POWER gain of an amplifier or other device in terms of db is:

$$db = 10 \log \frac{P \text{ output}}{P \text{ input}}$$

Q. 33. What is the impedance of a parallel circuit which is composed of a pure inductance and a pure capacitance at resonance? Of a series circuit at resonance? 4.

A. The impedance of a parallel circuit composed of a pure inductance and a pure capacitance at resonance would be infinite. If series connected, the impedance would be zero.

Q. 34. What is the "Q" of a circuit? How is it affected by the circuit resistance? How does the "Q" of a circuit affect bandwidth? 4.

A. The "Q" of a resonant circuit is its efficiency, or gain, or quality factor. The mathematical formula for "Q" is $\frac{\text{reactance}}{\text{resistance.}}$ As the resistance is increased, the "Q" decreases. The bandwidth decreases as the "Q" increases.

Q. 35. Draw a circuit diagram of a low-pass filter composed of a "constant-k" and an "M-derived" section. 13.

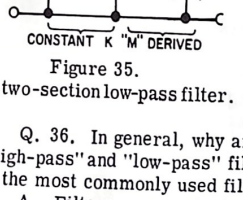


Figure 35.
A two-section low-pass filter.

M-derived and constant K sections enable the filter to have a constant impedance over a wide range of frequencies. This permits the design of filters with a high, equal attenuation over the attenuated band and a very low, equal attenuation over the pass band. A desirable, sharp cut-off characteristic is thus created.

Q. 36. In general, why are filters used? Why are "band-stop", "high-pass" and "low-pass" filters used? Draw schematic diagrams of the most commonly used filters. 7, 13.

A. Filters are used where some frequencies are to be passed and others rejected. "Band-stop" filters are used to eliminate a band of frequencies and to pass frequencies above and below this band. A "high-pass" filter is used to reject all frequencies below a certain point and pass all frequencies above this point. A "low-pass" filter is used to reject all frequencies above a certain point and pass all frequencies below this point.

Figures 36A, B and C illustrate commonly used filters.

Q. 37. Name four materials that make good insulators at low frequencies, but not at UHF or above. 1.

A. Four such insulators are: rubber, glass, bakelite and paper.

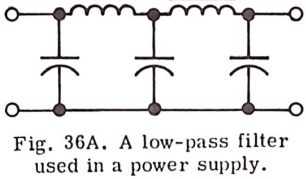


Fig. 36A. A low-pass filter used in a power supply.

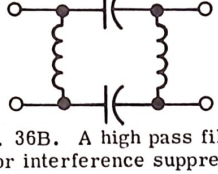


Fig. 36B. A high pass filter used for interference suppression.

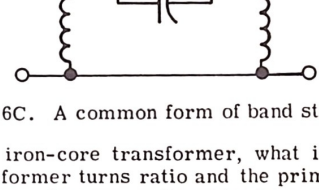


Figure 36C. A common form of band stop filter.

Q. 38. In an iron-core transformer, what is the relationship between the transformer turns ratio and the primary to secondary current ratio; between the turns ratio and primary to secondary voltage ratio? (Assume no losses). 4.

A. In an iron core transformer, the primary to secondary current ratio will vary inversely with the turns ratio. The voltage will vary in direct proportion to the turns ratio. For example, in a step-up transformer, the secondary has more turns and a higher voltage than the primary winding. However, the secondary current is less than the primary current.

Q. 39. What prevents high currents from flowing in the primary of an unloaded power transformer? 4.

A. The inductive reactance of the primary prevents the current in the primary of an unloaded transformer from becoming excessive.

Q. 40. An audio transformer has a resistive load connected across its secondary terminals. What is the relationship between this resistance, the turns ratio and the input impedance at the primary terminals? How is this principle useful in matching impedances? 9.

A. This question will best be answered by an example commonly encountered in transformer design. We have a tube which normally requires a 5000 ohm load for efficient operation. We wish to feed this tube to a speaker with an impedance of 4 ohms. What should be the turns ratio of the transformer used to match the two impedances? Answer; first we find the impedance ratio between the input impedance at the primary and the secondary load impedance. It is $\frac{5000}{4}$

or 1250 to 1. The turns ratio is equal to the square root of the impedance ratio. The turns ratio of the primary to secondary is therefore $\sqrt{\frac{1250}{1}}$ or 35.3 to 1.

Q. 41. How is power lost in an iron-core transformer? In an air-core transformer? 4.

A. Power losses in an iron core transformer occur in the iron and the copper wire. The iron core losses consist of eddy currents, hysteresis, leakage reactance and reluctance. Copper losses in the wire are due mainly to the resistance of the wire. In an air core transformer, the principal losses are due to copper wire resistance, skin effect (really a special case of resistance losses), leakage reactance and dielectric losses.

Q. 42. Explain the operation of a break-contact relay; a make-contact relay. 3.

A. A break-contact relay is one that breaks or opens a circuit when the coil is energized. A make-contact relay will make or close a circuit when the coil is energized.

Q. 43. What is the value and tolerance of a resistor which is color-coded (left-to-right): RED, BLACK, ORANGE, GOLD? 1.

A. 20,000 ohms. The last band, which is gold, is the tolerance. It indicates 5%.

Q. 44. Using the EIA standard six dot color system, what would be the value and tolerance of a capacitor whose first row colors are (from left-to-right): WHITE, RED, GREEN: second row: GREEN, SILVER, RED. 4.

A. We read the capacitor in a clockwise direction, starting with the white dot. The white dot indicates that the standard EIA system is to be used. The red dot indicates the number "2". The green dot indicates the number "5". The red dot of the bottom row indicates the number of zeros. The value is therefore 2500 pf. The silver dot indicates a ±10% tolerance. The green dot indicates capacity variation due to change in temperature. In this case, green indicates 0 to 70 parts per million per degree centigrade.

Q. 45. List three precautions which should be taken in soldering electrical connections to assure a permanent junction. 2.

A. To make a good electrical soldered joint, it is necessary to take the following precautions:

1. The parts to be soldered must be clean.
2. One must use sufficient heat to heat the work and the solder so that the solder and flux flow smoothly over the work.
3. A good grade of solder and flux must be used.
4. The iron must be clean and properly tinned.

ELECTRON TUBES

Q. 46. Discuss the physical characteristics and a common usage of each of the following electron tube types: 6, 8, 15.

(a) diode (b) triode (c) tetrode (d) pentode (e) beam power (f) remote cut-off (g) duo-triode (h) cold-cathode (i) thyratron

A. (a) A diode is a 2-element tube. The physical structure is an electron emitting cathode and a piece of metal, insulated from the cathode, which is called the plate. The cathode can be either a nickel ribbon, or it can consist of a filament which heats a nickel sleeve. In this second case, the nickel sleeve emits the electrons. The plate is usually a metal sleeve surrounding the cathode. In some tubes, the plate is a flat plate or cup spaced a distance from the cathode. Electrons flow from the cathode to the plate. Diodes are used in power supplies as rectifiers. A rectifier changes AC to DC.

(b) A triode contains a third element in addition to the two elements found in the diode. See Figure 46. The third element is called a control grid. It is a thin wire wound in the form of a spiral, and is placed between the cathode and the plate. The control grid controls the flow of electrons between the cathode and plate. Triodes are used in RF oscillator or amplifier circuits.

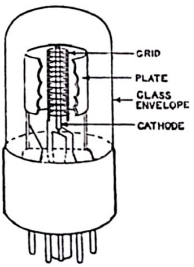


Figure 46.
A triode vacuum tube.

(c) The tetrode has the same elements as the triode, plus an additional thin wire grid called the "screen grid". The screen grid is placed between the control grid and the plate. Tetrodes are used in RF amplifier circuits.

(d) The pentode has the same elements as the tetrode, plus an additional fine wire grid located between the screen grid and the plate. This third grid is called a "suppressor grid". Pentodes are used in almost every type of oscillator, audio amplifier or RF amplifier or RF amplifier circuit.

(e) The beam power tube is basically a pentode with special constructional features. A beam power tube has greater power handling ability than does the conventional tetrode or pentode. The tube is so constructed that the wire turns of the control grid and screen grid line up with each other horizontally; each turn of the screen grid

mesh is directly behind a turn of the control grid mesh. Thus, electrons flowing from the cathode travel through the control grid and on to the plate without striking the screen grid. Because of the physical alignment of the control grid and the screen grid, the electrons flow to the plate in sheets, or beams. To further concentrate and form heavy beams of plate current, deflecting plates are incorporated into the tube structure, and are placed between the screen grid and the plate, extending part way around the tube. Since these beam forming plates are internally connected to the cathode, they acquire a negative charge with respect to the plate. As a result, the deflecting plates repel the electrons and form them into concentrated, heavy beams of plate current. No actual suppressor grid is necessary since secondary emission from the plate is suppressed by the space charge which forms between the plate and screen grid. Beam power tubes are used in audio power amplifiers in ordinary broadcast receivers.

(f) A remote cutoff tube is one in which the control grid is modified, usually in the spacing of the wires over part of its length, to extend the voltage at which the plate current is cut off. The principal use for the remote cutoff tubes is in amplifiers where the gain must be varied by a voltage, without excessive distortion of the signal. The IF tubes in a radio receiver that are controlled by the automatic gain control (AGC or AVC) are usually remote cutoff types.

(g) A duo-triode is a tube with two triode tubes in one envelope. This is usually done to save space and cost.

(h) A cold cathode tube is one in which the cathode is not heated to produce electron emission. A gas in the tube ionizes and causes electrons to flow between the cathode and plate. Cold cathode tubes can be diodes (see above) or triodes. The third element is used to control the beginning of the arc across the other two elements. It is a trigger. Cold cathode tubes can be used as voltage regulators.

(i) A thyratron is a gas-filled triode or tetrode tube. The thyratron is used to control large amounts of power flow by means of control grid action. When the grid of a thyratron is sufficiently negative, no plate current flows. However, if the bias is lowered to the point where plate current begins, the gas in the tube immediately ionizes and a heavy plate current flows. At this point, the control grid loses control over the plate current. Varying the bias voltage after plate current starts will have no effect on the plate current. The only way to stop the flow of plate current is to remove the plate voltage, or lower it below the ionization potential of the gas. The thyratron grid, therefore, acts as a trigger to turn on relatively large currents in the plate circuit. Thyratrons also function as high voltage rectifiers, such as the 885 and 885 triodes, or the 2D21 tetrode.

Q. 47. What is the principal advantage of a tetrode tube over a triode tube as a radio-frequency amplifier? 13.

A. The tetrode does not require neutralization as does the triode.

Q. 48. Compare tetrode tubes to triode tubes in reference to high plate current and interelectrode capacitance. 8.

A. A triode tube grid to plate capacity is typically several picofarads. A tetrode grid to plate capacity is in the range of 0.1 to 0.4 pf. The other interelectrode capacities are similar, with the tetrode having slightly higher values than the triode.

A tetrode will have a much higher plate current than a triode when the plate voltage is low and the grid voltage is near zero or positive. During other conditions, the tetrode tends to be capable of higher plate currents than the triode.

Q. 49. Are there any advantages or disadvantages of filament type vacuum tubes when compared with the indirectly heated types? 6.

A. An advantage of the filament type vacuum tube is that it can usually handle higher voltage and power levels than the indirectly heated type. A disadvantage of the filament type of tube is that the hum from the AC in the filament manages to get into the signal. Also, because of the uneven wear of the filament, the tube life of the filament type tubes is shortened.

Q. 50. Draw a simple circuit diagram of each of the following and describe their operation. Show a signal source, and include coupling and by-pass capacitors, power supply connections and plate load.

(a) AF "grounded-cathode" triode amplifier with cathode resistor biasing, as for Class A operation. 9.

(b) AF "grounded-cathode" pentode amplifier with battery biasing, for Class A operation. 8, 9.

(c) RF "grounded-grid" triode amplifier with LC tank plate-load for Class B operation. 13.

(d) AF "cathode-follower" triode amplifier. 9.

(e) AF "push-pull" pentode amplifier, operated Class B with transformer coupling to a speaker. 9.

A. (a) See question and answer 110A.

(b) A pentode grounded-cathode amplifier is shown in Figure 50B. The operation of this circuit is essentially the same as the triode discussed in 50A (110A) with the following differences. Grid bias is provided by a battery (resistor R_k and capacitor C_k are not required). Voltage is applied to the screen grid through resistor R_S. The screen grid has the effect of greatly increasing the gain of the tube. It also reduces the grid-to-plate capacitance, thereby improving the high frequency response of the amplifier. Capacitor C_S by-passes the screen to ground at the signal frequencies.

The suppressor grid in the tube is connected to the cathode. The sole function of the suppressor grid is to eliminate secondary emission of the electrons from the plate.

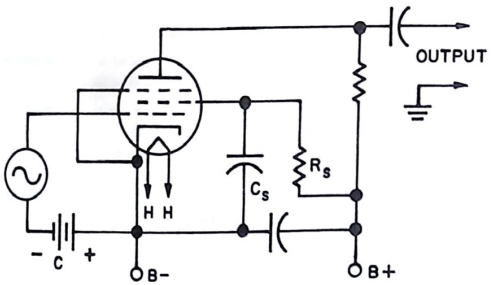


Figure 50B. A pentode grounded cathode amplifier.

(c) The circuit of a Class B grounded-grid triode amplifier is shown in Figure 50C. Note that the grid is grounded and the signal is applied to the cathode. No neutralizing capacitor is required because the grid effectively isolates the cathode from the plate.

Class B operation requires that the grid be biased at "cut-off" and hence the plate current will flow during only one-half of the cycle. However, the L_1C_2 tank circuit exhibits what is known as the "flywheel effect". This means that the LC circuit is excited and provides the remaining one-half cycle of voltage.

The grounded-grid amplifier requires much higher driving power than the corresponding conventional grounded-cathode amplifier. However, most of the input power is transferred to the output circuit of the tube.

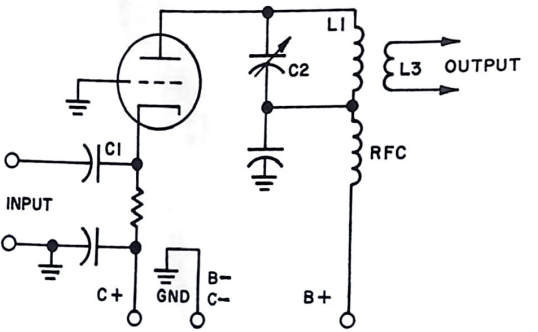


Figure 50C. A Class B grounded grid triode amplifier.

(d) See Answer 110B.

(e) The circuit of a Class B push-pull pentode amplifier is shown in Figure 50E. The value of the bias voltage Ecc is chosen so that with no input signal, little or no plate current flows in either tube. When a signal is applied, one tube conducts during the positive half of the signal and the second tube conducts during the negative half. The output voltage is developed across the output transformer.

The Class B circuit is capable of higher power output and efficiencies approaching 78.5% can be realized. This is greater than the efficiency of the Class A push-pull amplifier (see Question 110F). Since little or no plate current flows when no signal is applied, almost no plate power is consumed when no input signal is present. In addition, even-order harmonics are cancelled out in the output transformer. Note too, that since I_{b1} and i_{b2} flow in opposite directions through the primary of the output transformer, the net DC plate current flowing through the primary winding is zero. This means that distortion due to DC saturation of the core is avoided.

Disadvantages of the Class B push-pull amplifier compared with Class A are: higher harmonic distortion, self-bias cannot be used and higher signal and drive requirements.

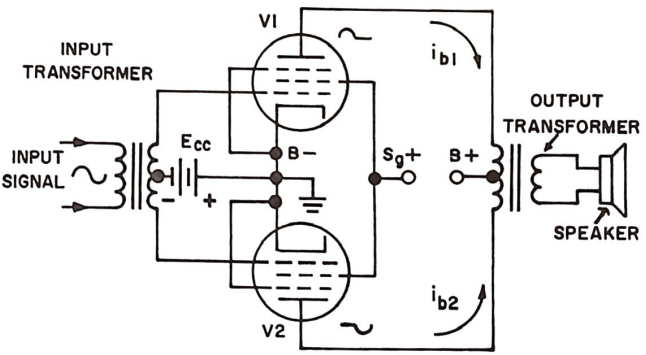


Figure 50E. A Class B push-pull pentode amplifier.

Q. 51. What kind of vacuum tube responds to filament reactivation and how is reactivation accomplished? 6.

A. Filaments consisting of thoriated tungsten can be reactivated. Reactivation is accomplished by raising the filament voltage to twice

the normal voltage for a period of one minute. We then reduce the voltage to about 25% above normal for a two hour period.

Q. 52. Draw a rough graph of plate-current versus grid-voltage (Ip vs. Eg) for various plate voltages on a typical triode vacuum tube.

(a) How would output current vary with input voltage in Class A amplifier operation? Class AB operation? Class B operation? Class C operation? 8, 9.

(b) Does the amplitude of the input signal determine the class of operation? 9.

(c) What is meant by "current-cutoff" bias voltage? 8, 9.

(d) What is meant by plate-current "saturation"? 8.

(e) What is the relationship between distortion in the output current waveform and: (1) the class of operation. (2) the portion of the transfer characteristic over which the signal is operating? (3) amplitude of input signal. 9.

(f) What occurs in the grid-circuit when the grid is "driven" positive? Would this have any effect on biasing? 9.

(g) In what way is the output current related to the output voltage? 9.

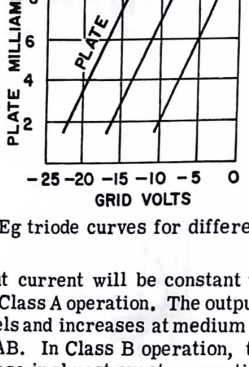


Figure 52. Ip vs. Eg triode curves for different plate voltages.

A. (a) The output current will be constant with varying input voltage in Class A operation. The output current is steady at low levels and increases at medium to high input levels in Class AB. In Class B operation, the output current will increase in almost exact proportion to the increase in signal input. As a Class C amplifier is biased beyond cutoff (fixed bias is assumed), there will be no plate current until the signal becomes quite large. Above that point the current will rise rapidly with increasing signal amplitude.

(b) The amplitude of the signal does not determine the class

of operation. However, it contributes to the determination as follows: In a Class AB amplifier, at extremely low signal levels, the amplifier is actually operating Class A. This is because the plate current is not cut off during any part of the cycle. As soon as the plate current is cut off during any part of the cycle, it is no longer operating Class A, but operates in Class AB.

(c) Current cutoff (plate current) bias voltage is that level of negative voltage applied to the control grid of a tube that will just prevent the flow of plate current.

(d) Plate current saturation is the condition where an increase in plate voltage will not produce any increase in plate current.

(e) Waveform distortion is least in Class A, medium in Class B and greatest in Class C operation. Distortion is least when the signal is entirely within the limits of the linear portion of the tube's characteristic curve. Distortion is greatest when operating in the curved portions or partly outside of the tube's characteristic curve. Distortion is least at lower signal amplitudes.

(f) When the grid is driven positive, the grid will attract electrons and therefore take current. If the grid circuit has very low resistance and zero fixed bias, and the signal source has very low impedance, there will be little effect on the bias. In a more common condition, the grid circuit has a relatively high resistance and any grid current will produce a voltage drop across that resistance and change the bias. In many Class C amplifiers, the grid circuit resistance and capacity are used as the only source of grid bias. In a Class A amplifier, when it is driven past or even near the grid current point, the distortion is usually more than can be tolerated.

(g) (Output current is assumed to mean plate current). The output current increases when the output voltage is increased.

or

The output current (assuming a resistive load) is proportional to the output voltage.

Q. 53. What is meant by "space charge"? By "secondary emission? 6, 8.

A. A "space charge" is a negatively charged cloud of electrons that exists in a vacuum tube between some of the elements.

"Secondary emission" is the emission of electrons from a surface that is being bombarded with other electrons. In the case of vacuum tubes, it is the electrons that are dislodged from the plate because the plate is being hit with electrons from the cathode.

Q. 54. What is meant by the "amplification factor" (mu) of a triode vacuum tube (amplifier)? Under what conditions would the amplifier gain approach the value of mu? 8.

A. The amplification factor of a triode vacuum tube is the ratio of the change in plate voltage to the change in grid voltage that produces the same change in plate current. The gain of an amplifier stage will approach the amplification factor as the plate load impedance approaches infinity.

Q. 55. What is meant by "plate resistance" of a vacuum tube? Upon what does its value depend? 8.

A. The plate resistance is the internal resistance between the cathode and plate to the flow of varying plate current. Mathematically speaking, it is the ratio of a small change in plate voltage to the change in plate current that the voltage change produced. It is expressed in the following equation:

$$\text{Plate Resistance } (R_p) = \frac{\Delta E_p}{\Delta I_p}$$

Where ΔE_p is the change in plate voltage and ΔI_p is the change in plate current.

Q. 56. What is meant by the voltage "gain" of a vacuum tube amplifier? How does it achieve this gain? 8.

A. The voltage "gain" of a vacuum tube amplifier is the multiplication that a signal at the input of the amplifier receives in going through the amplifier.

The signal achieves this gain because of the tube's amplification and the amplification inherent in the various transformers and tuned circuits.

Q. 57. Draw a rough graph of plate-current versus plate supply voltage for three different bias voltages on a typical triode vacuum tube. 8.

(a) Explain, in a general way, how the value of the plate load resistance affects the portion of the curve over which the tube is operating. How is this related to distortion?

(b) Operation over which portion of the curve produces the least distortion?

A. The curves, known as "plate characteristics", for three different bias voltages are shown in Figure 57A.

(a) The value of the plate load resistance (R_L) determines the "load line" of the amplifier stage. Three load lines are drawn on the characteristics curves in Figure 57A. Each line corresponds to a different load resistance. Each load line indicates the actual tube plate current (ib) and plate voltages (eb) which will exist as the grid voltage

is varied. For example, for a grid voltage of e_{c1}, the plate voltage (eb) will be e_{b1}. As the grid voltage changes to points e_{c2} and e_{c3}, the corresponding plate voltages (e_b) and plate currents can be determined from the intersection of the grid curves (e_{c1}, e_{c2} or e_{c3}) with the load line.

(b) Operation over the portion of the load line where the spacing is equi-distant produces the lowest distortion. This occurs over the linear portion of the curve. In Figure 57B the plate characteristic curves are redrawn with two of the load lines. Also, the grid curves are assumed to have the values -1, -2, and -3 volts. Note that a grid voltage change from -3 volts to -2 volts and finally to -1 volt along load line #1 will mean that equal portions of the load line will be traversed. This will mean equal changes in plate current (i_b). This will mean little or no distortion is generated. However. the same grid voltage

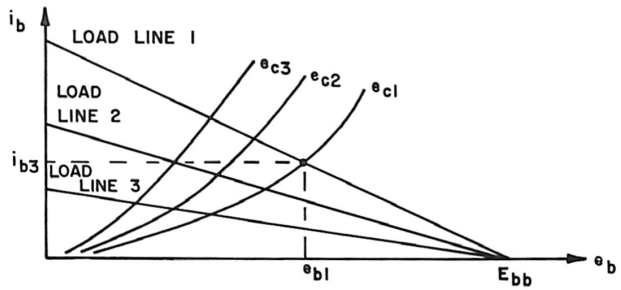


Figure 57A. Plate current-plate voltage triode curves for various bias voltages.

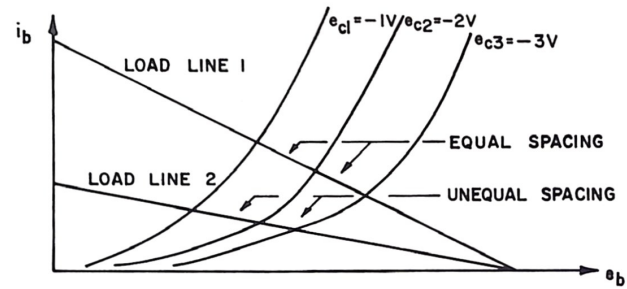


Figure 57B. Operation over different portions of the curve.

changes along load line #2 will traverse unequal portions of this load line, hence changes of i_b will not be equal and the output current will be distorted, thereby distorting the signal.

Q. 58. A triode, "grounded cathode", audio amplifier has a "mu" (amplification factor) of 30, a plate impedance of 5,000 ohms, a load impedance of 10,000 ohms, a plate voltage of 300 volts and a plate current of 10 ma. Cathode-resistor bias is used.

(a) What is the stage gain of this amplifier? 8.

(b) What is the cutoff-bias voltage, E_{co}? 9.

(c) Assuming the bias voltage is one-half the value of E_{co}, what value cathode resistor would be used to produce the required bias? 2, 9.

(d) What size capacitor should be used to sufficiently bypass the cathode resistor if the lowest approximate frequency desired is 500 cycles per second? 9.

A. (a) The gain is 20. It is calculated as follows:

$$\text{gain} = \frac{\mu R_L}{R_L + R_p} = \frac{30 \times 10,000}{10,000 + 5,000} = \frac{300,000}{15,000} = 20$$

Where μ is the amplification factor, R_L is the load impedance and R_p is the plate impedance.

(b) $E_{co} = -10V$. This is found by using the formula which gives the approximate cutoff bias.

$$E_{co} = -\frac{Eb}{\mu} = -\frac{300}{30} = -10 \text{ volts}$$

Where E_{co} is the cut-off bias, E_b is the plate voltage and μ is the amplification factor.

(c) $R_c = 500$ ohms. This is found by using Ohm's law.

$$R_c = \frac{E_R}{I_p} = \frac{5}{.010} = 500 \text{ ohms}$$

Where R_c is the cathode resistance, E_R is the required bias voltage and I_p is the plate current.

(d) A good rule of thumb is that the capacitive reactance of the by-pass capacitor should be one-tenth of the resistance of the cathode bias resistor at the lowest frequency to be passed. Xc must therefore be 50 ohms. We then substitute in the following formula to arrive at the value of C.

$$X_c = \frac{1,000,000}{2\pi fc.} \qquad C = \frac{1,000,000}{2\pi X_c f} = \frac{1,000,000}{6.28 \times 50 \times 500} = \frac{1,000,000}{157,000} =$$

$$C = 6.36 \text{ mfd.}$$

Where: f is in cycles and C is in mfd.

The answer to the problem is 6.36 mfd. Since this is not a standard value, we would probably use 10 mfd.

Q. 59. Why is the efficiency of an amplifier operated Class C higher than one operated Class A or Class B? 13.

A. In Class C operation, plate current flows for less time per cycle than it does for Class A or Class B. There is, therefore, less power dissipated inside the tube and more output power available in Class C operation.

Q. 60. The following are excerpts from a tube manual rating of a beam pentode. Explain the significance of each item: 6, 7, 8, 9.

(a) Control grid-to-plate capacitance ..... 1.1 pf
(b) Input capacitance ..... 2.2 pf
(c) Output capacitance ..... 8.5 pf
(d) Heater voltage ..... 6.3 volts
(e) Maximum DC plate-supply voltage ..... 700 volts
(f) Maximum peak positive pulse voltage ..... 7,000 volts
(g) Maximum negative pulse plate voltage ..... 1,500 volts
(h) Maximum screen grid voltage ..... 175 volts
(i) Maximum peak negative control grid voltage .... 200 volts
(j) Maximum plate dissipation ..... 20 watts
(k) Maximum screen-grid dissipation ..... 30 watts
(l) Maximum DC cathode current ..... 200 ma.
(m) Maximum peak cathode current ..... 700 ma.
(n) Maximum control-grid circuit resistance ....0.47 megohm

A. (a) Control Grid-to-Plate Capacitance. Since the grid and plate in a pentode are separated by a vacuum dielectric, they form a capacitor. When the pentode is used as an amplifier, low grid-to-plate capacitance is desirable. This is because this capacitance provides a feedback path tending to make the amplifier oscillate. Consequently, the lower the grid-to-plate capacitance, the less the likelihood of oscillation.

(b) Input Capacitance. The formula for input capacitance is:
Input Capacitance = $C_{gc} + C_{me} + C_s$

Where C_{gc} is the grid-to-cathode capacitance

C_{me} is the "Miller Effect Capacitance"

C_s is the stray capacitance due to wiring and tube socket pins.

Since a high input capacitance shunts the input, and since this capacitance approaches a short circuit at high frequencies, a low value is necessary for good frequency response.

(c) Output Capacitance. The output capacitance of a pentode is the sum of the plate-to-cathode capacitance and stray wiring and tube socket capacitances. A low value is

desirable for good high frequency response.

(d) Heater Voltage. The heater voltage is the voltage required by the filament to assure both the proper electron emission and an adequate service life of the tube. Too high a heater voltage will damage the emitting surface of the cathode. If the heater voltage is too low, the cathode emission will be too low.

(e) Maximum DC Plate-Supply Voltage. The maximum DC plate voltage is the maximum DC voltage which can be safely applied between the plate and cathode. Exceeding the manufacturer's rated maximum DC plate supply voltage rating may cause internal arcing or excessive plate dissipation resulting in permanent damage to the tube.

(f) Maximum Peak Positive Pulse Voltage. The maximum peak positive pulse voltage is the maximum instantaneous voltage which can occur between the plate and cathode without destruction to the tube. Assuming that the peak is a very short-duration pulse, this value would be limited by the spacing of tube elements and the maximum filament emission and not by the plate dissipation capabilities of the tube.

(g) Maximum Negative Pulse Plate Voltage. This voltage is the maximum potential that can be applied in the reverse direction (cathode plus, plate minus). This value is determined by the spacing of the tube elements and, if exceeded, may cause arcing.

(h) Maximum Screen Grid Voltage. The maximum screen grid voltage is the largest voltage that can be applied between the screen grid and cathode. The value is restricted by the maximum screen grid dissipation.

(i) Maximum Peak Negative Control Grid Voltage. The maximum peak negative control grid voltage is the maximum instantaneous negative voltage which can be applied between the grid and the cathode. This value is determined by the grid-to-cathode spacing and, if exceeded, may result in arcing and destruction of the tube elements.

(j) Maximum Plate Dissipation. The maximum plate dissipation is the maximum power (in watts) which can be dissipated by the plate of the tube. The power dissipated by the plate is due to electron bombardment of the plate and is the difference between the DC power delivered to the plate and the output power delivered by the tube.

(k) Maximum Screen Grid Dissipation. Screen-grid heating results from the portion of the electron flow from the cathode which collides with the screen-grid. This heat must be dissipated. The maximum screen grid dissipation is the maximum power in watts which can be dissipated by the screen without excessive heating or damage.

(l) Maximum DC Cathode Current. The maximum DC cathode current is the maximum steady state current which can flow from the cathode without destruction of the cathode surface.

(m) Maximum Peak Cathode Current. This current is the maximum instantaneous cathode current which may flow without destroying the cathode. Oxide-coated cathodes can endure high momentary peak currents if the interval between pulses is 0.1 second or more. This is sufficient time for the cathode to rejuvenate its emitting surface.

(n) Maximum Control-Grid Circuit Resistance. Small quantities of positive ions are collected by the negatively-biased control grid. As the resistance between the control grid and the cathode is increased, the positive ion flow through the control grid resistance will develop counteracting positive bias, thereby increasing the plate current. This may overheat the tube, liberating more ions so that a runaway condition may develop which will destroy the tube. The maximum control-grid circuit resistance is the limiting value specified by the manufacturer to insure that the grid maintains proper control and remains undamaged by ion multiplication runaway.

Q. 61. Name at least three abnormal conditions which would tend to shorten the life of a vacuum tube, also name one or more probable causes of each condition. 6, 7, 8.

A. (a) One abnormal condition would be excessive plate current. This could be caused by insufficient grid bias due to a defective bias supply. Another cause could be lack of drive in a Class C self biased RF amplifier.

(b) A second abnormal condition could be excessive grid current. This could be caused by inadequate bias or excessive drive.

(c) A third abnormal condition is excessive screen current. This could be caused by poor screen voltage regulation.

Q. 62. Name at least three circuit factors (not including tube types and component values) in a one stage amplifier circuit, that should be considered at VHF which would not be of particular concern at VLF. 19.

A. The following factors require special attention at VHF frequencies:

(1) Neutralization. Many circuits that do not require neutralization at lower frequencies must be neutralized at the higher frequencies. This is due to the stray capacitances and inductances that are not important at the lower frequencies.

(2) Components. Components should be used that are designed for high frequencies. Their insulation is of the low-loss type. For example, mica sockets would be used instead of bakelite sockets. The leads on components designed for high frequencies are such that their inductances and capacitances are at a minimum.

(3) Circuits. Circuits are used that have a minimum plate circuit to grid circuit capacity. This will reduce the possibility of oscillation due to feedback between the plate and grid circuits. The grounded-grid type of amplifier is used in high frequency circuits to reduce the possibility of feedback.

(4) Skin Effect. Since high frequency RF current flow is substantially limited to the surface of the conductor, silver plating is often used to improve conduction.

Q. 63. What is a "lighthouse" triode? An "acorn" tube? These tubes were designed for operation in what frequency range? 19.

A. The "lighthouse" triode is a vacuum tube designed for operation in the UHF range. The essential characteristic of this triode is that it is designed to be a physical part of the UHF circuit. The lighthouse tube uses rods and tubing as elements. This construction enables the tube to be a physical part of the coaxial and tuned-line tank circuits. Lead inductance which can impair vacuum tube operation at high frequencies is virtually eliminated. Elements are closely spaced to reduce transit time effects. Lighthouse tubes are found in both oscillator and amplifier circuits.

Acorn tubes, so named because of their physical similarity to an acorn, are small vacuum tubes designed for UHF service. The tube is distinguished by its lack of a tube base. All the tube elements emerge directly from the tube. Heater, cathode, screen and suppressor leads are spaced radially about the glass envelope. This construction reduces lead inductance. In some acorn tubes, the plate lead emerges from the top and the grid lead protudes from the bottom, providing excellent grid-plate isolation.

Q. 64. Why are special tubes sometimes required at UHF and above? 19.

A. Conventional vacuum tubes are hampered by "transit time" effect. This means that, at higher frequencies, the time which elapses when an electron passes from the cathode to the plate approaches a significant portion of the time of a complete cycle of the signal. This results in reduced operating efficiency. In tubes designed for UHF, transit time effects are minimized by positioning the electrodes very close together. For example, the so-called "lighthouse tubes" have elements spaced one-thousandth of an inch apart.

The high interelectrode capacitances and lead inductances make low frequency tubes unsuitable for UHF operation. Consequently,

UHF tubes are so constructed to reduce both interelectrode capacitances and lead inductances to the minimum (See Question 63).

Q. 65. Draw a diagram of each of the following power supply circuits. Explain the operation of each, including the relative input and output voltage amplitudes, waveshapes and current waveforms.

(a) Vacuum-tube diode, half-wave rectifier with a capacitive-input "pi-section" filter. 7.

(b) Vacuum-tube diode, full-wave rectifier with choke input filter. 7.

(c) Silicon diode, doubler-circuit rectifier with a resistive load. 7.

(d) Nonsynchronous-vibrator power supply, with silicon diode, bridge-circuit rectifier and capacitive input "pi-section" filter. 7.

(e) Synchronous-vibrator power supply with capacitive input "pi-section" filter. 7.

A. (a) Figure 65A1 is a circuit of a diode half-wave rectifier with a capacitive-input filter. The diode allows current to flow in only one direction, thereby changing AC to pulsating DC. The filter, consisting of C1, L and C2, smooths out the pulsating DC and makes it pure DC. It does so in the following manner: C1 and C2 provide a path to ground for the AC ripple because a condenser passes AC. The condensers block DC and prevent it from going to ground. The choke "L" opposes the AC ripple, but does not oppose the DC. Thus, the action of C1, C2 and "L" prevents the AC component from getting to the load while allowing the pure DC to get to the load.

(b) The full wave rectifier utilizes the entire AC cycle to provide power. AC power applied to the primary of a power supply is usually stepped up to a higher voltage and then is applied by means of the secondary winding to the plates of the diodes. (See Figure 65B1). When the plate of diode #1 is positive, the plate of diode #2 is negative. Current will flow through diode #1 but not through diode #2. On the next half cycle, the plate of diode #1 will be negative and the plate of diode #2 will be positive. There will be no current flow in diode #1, but current will flow in diode #2. The tube current frequency is, therefore, twice that of the input frequency. This is graphically illustrated in Figure 65B2.

The filter action is similar to that described above. Because the ripple frequency of a full wave rectifier is twice that of a half wave rectifier, the output of a full wave rectifier is easier to filter than that of a half wave rectifier.

(c) The doubler circuit, shown in Figure 65C1, utilizes capacitor C1 as a secondary voltage source so that capacitor

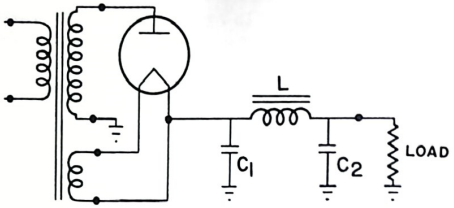


Figure 65A. A half-wave rectifier.

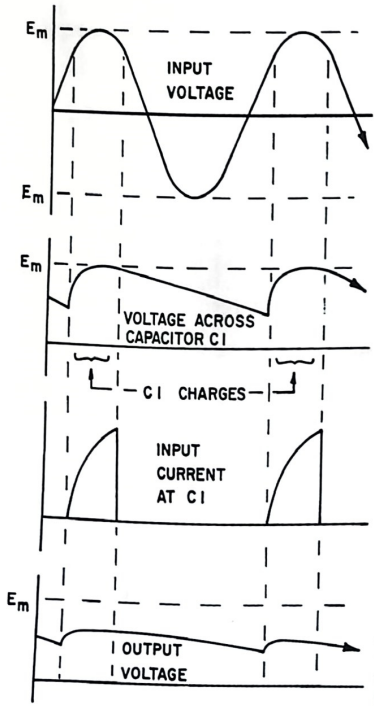


Figure 65A2. Voltage and current waveforms in a half-wave rectifier.

C2 can be charged up to twice the voltage. During the negative portion of the first cycle of operation, capacitor C1 is charged up to the peak transformer voltage(Em). Current from the transformer flows from point B through A and then through capacitor C1. No current flows through C2 and D2 because diode D2 is back biased and hence, non-conducting. When the AC voltage begins to go positive, the diode D1 stops conducting and D2 begins to conduct. Capacitor C2 charges up to 2Em. This is the sum of the peak voltage of the transformer (Em) and the voltage on capacitor C2 (Em).

Note that the output voltage will have a slight ripple. This is due to the discharge of current through the load during the portion of the cycle when diode D2 is not conducting.

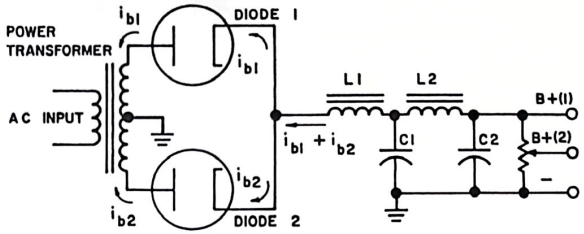


Figure 65B1. A full-wave rectifier with choke input filter.

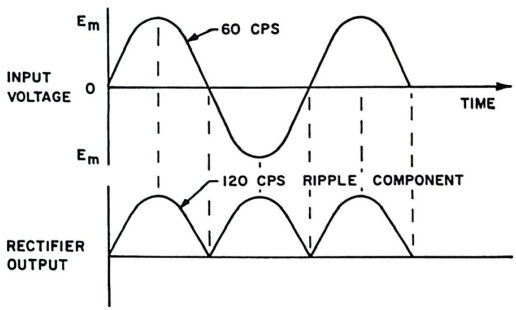


Figure 65B2. Input and output wave forms of a full-wave rectifier.

However, C2 is recharged to Em every cycle. Resistors R1 and R2 are current limiting resistors. They prevent high currents from damaging the diodes during the first cycle of operation.

(d) Figure 65D shows a schematic diagram of a non-synchronous vibrator power supply. This power supply converts low voltage DC into high voltage DC in the following manner: The vibrator is shown in the dotted line. When the switch is turned on, current will flow from A- through the vibrator's electromagnet, up through the bottom half of the transformer's primary and back to A+. The energized electromagnet will pull the vibrating reed, R, down to contact "C", causing a heavy current to flow through the bottom of the primary of the transformer. At the same time, the electromagnet will be shorted out and the reed will be released and will move back to its normal

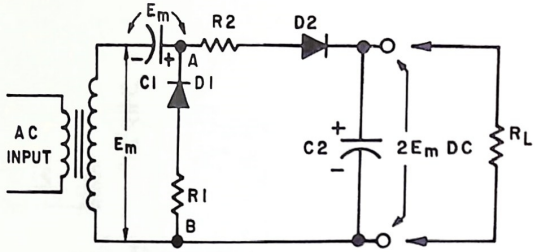


Figure 65C1. A silicon diode voltage doubler circuit.

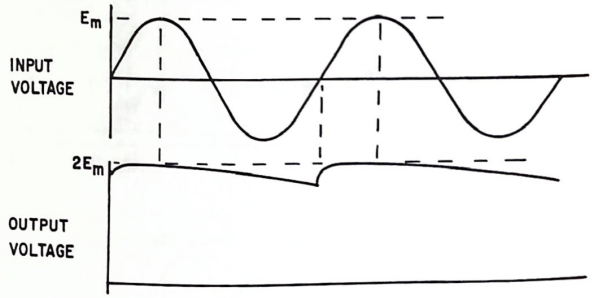


Figure 65C2. Input and output voltage waveforms of a doubler circuit.

position shown in the schematic. Inertia will cause the reed to move past its normal position and over to contact "D". This will cause a heavy current to flow through the top half of the primary of the transformer. The reed will then return to its normal position, the current in the top half of the transformer will cease and the vibrator's electromagnet will start the cycle all over again. You will note that the current flows through the primary, first in one direction, then in the other. This is similar to AC. The turns ratio of the transformer is such that high AC voltage will appear across the secondary. This will be changed to DC by the bridge rectifier and filtered by the filter.

(e) A circuit diagram of a synchronous vibrator power supply unit is shown in Figure 65E. The vibrating reed operates in a similar manner to the one shown above in 65D to produce a high AC voltage at the transformer's secondary. However, an extra set of contacts is added to the vibrator (contacts E and F). The output of the transformer is fed back to contacts E and F. As the reed vibrates, the top and bottom of the transformer's secondary is alternately

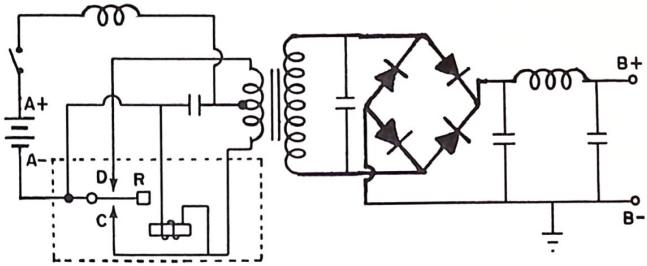


Figure 65D. A non-synchronous-vibrator power supply.

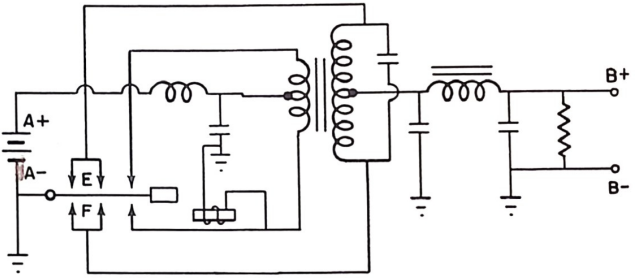


Figure 65E. A synchronous-vibrator power supply.

grounded, while the center is always positive with respect to the ends. The current in the secondary of the transformer is actually a pulsating DC, thereby eliminating the need for a rectifier tube. The pulsating DC is then filtered in the usual manner by the filter circuit.

Q. 66. What advantage may a bridge rectifier circuit have over a conventional full-wave rectifier? 7.

A. A bridge rectifier makes use of the entire secondary voltage of the transformer while a conventional full-wave rectifier uses only one half the voltage of the secondary. The voltage output of a bridge rectifier is, therefore, twice the output of a conventional full wave rectifier using the same transformer. Note that the bridge rectifier of Fig. 65D does not have a center-tapped secondary, while the full wave rectifier of Fig. 65B1 does.

Q. 67. What are "swinging chokes"; where are they normally used?

A. A swinging choke is one where inductance varies as the current through it varies. The inductance varies in such a way that its reactance remains constant with varying currents through it. This characteristic makes the swinging choke ideally suited for transmitter

power supplies where large load current changes take place and where good voltage regulation is important. The voltage drop across the choke will tend to remain constant and keep the output B+ voltage constant.

Q. 68. Show a method of obtaining two voltages from one power supply. 7.

A. See Figure 65B1. Note voltage B+ (1) and B+ (2).

Q. 69. What are the characteristics of a condenser-input filter system as compared to a choke-input system? What is the effect upon a filter choke of a large value of direct current flow? 7.

A. The condenser input filter system has a higher output voltage and poorer voltage regulation as compared to a choke input system. A large value of direct current flow through a choke will cause saturation and an effective reduction of its inductance.

Q. 70. What is the purpose of a "bleeder" resistor as used in connection with power supplies? 7.

A. A bleeder improves the voltage regulation of the power supply by providing a minimum fixed load for the power supply. It also discharges the condensers after the power has been turned off and is thus a safety aid.

Q. 71. Would varying the value of the bleeder resistor in a power supply have any effect on the ripple voltage? 7.

A. Yes. If we decrease the value of the bleeder resistor, we will increase the load on the power supply and this will increase the ripple voltage.

Q. 72. What effect does the amount of current required by the load have upon the voltage regulation of the power supply? Why is voltage regulation an important factor? 7.

A. Increasing the load current decreases the voltage regulation of a given power supply. Regulation is usually expressed as follows:

$$\% \text{ Regulation} = \frac{E_{NL} - E_{FL}}{E_{FL}} \times 100$$

Where: E_{NL} is the no-load voltage and
E_{FL} is the full-load voltage.

From the formula, it can be seen that a larger load will cause a lower full-load voltage which in turn will cause a higher % Regulation. A higher percentage regulation indicates a poorer regulation. A well-regulated power supply should provide almost the same voltage under full-load conditions as under no-load conditions. Voltage regulation is an important factor in those cases where the load has continuously changing current requirements. Class AB_1, AB_2 and B amplifiers

have changing current requirements and therefore, a well-regulated power supply is necessary for their proper operation.

Q. 73. What is meant by the "peak-inverse-voltage" rating of a diode and how can it be computed for a full-wave power supply? 7.

A. The peak-inverse-voltage is the maximum voltage which a diode can withstand without destruction when the polarity of applied voltage is such that current does not flow through the diode (reversed polarity).

To compute the peak-inverse-voltage for a full-wave power supply, multiply the full-transformer secondary voltage by 1.414 and subtract the voltage drop which occurs across the diode during conduction.

Q. 74. Discuss the relative merits and limitations as used in supplies of the following types of rectifiers: 7.

(a) Mercury vapor diode
(b) High vacuum diode
(c) Copper oxide
(d) Silicon
(e) Selenium

A. (a) Mercury vapor rectifier tubes offer substantially better conduction properties than comparable high voltage (non-gaseous) rectifier tubes. The internal voltage drop of a mercury vapor rectifier tube is 10 to 15 volts. This value is independent of the current so that regulation is superior to that obtainable with high vacuum tubes. Cool operation also results from the fixed, low voltage drop.

Since radio frequency noise (hash) may be generated by mercury vapor rectifier tubes, RF chokes must often be connected in series with the plate terminals of the tubes to prevent the noise from reaching other circuits. During normal operation, the filament of a mercury vapor rectifier tube must be brought to operating temperature about 25 seconds prior to the application of plate power, otherwise the filament may be damaged.

(b) High-vacuum diodes will withstand more abuse and higher relative inverse peak voltages than comparable mercury vapor tubes. They are most often used in low voltage, low current power supplies (approximately 600 volts or less). However, high vacuum rectifiers have higher internal voltage drops which vary with tube current. Consequently, regulation will be poorer than can be obtained from mercury vapor tubes.

(c) Copper oxide rectifiers are restricted to low frequency applications. They are most often utilized as meter rectifiers in conjunction with DC voltmeters which are used to measure AC power line voltages and audio frequency voltages. The reason for the restriction to low frequency

is the inherent high shunt capacitance of the copper oxide diode.

(d) Silicon diodes are noted for their very small physical size per watt of output power and the broad temperature range over which satisfactory operation can be obtained. Operating temperatures of the diode junction may approach 390°F without destruction of the diode junction. The diodes have a current density of approximately 750 amperes per square inch of junction area so that large currents can be carried by relatively small diodes.

However, peak currents are extremely critical because the diodes are quite small and should a large pulse of current pass through the diode, heating may occur so rapidly that destruction of the junction occurs. Consequently, current limiting resistors must be placed in series with the diodes to prevent destruction.

(e) Selenium rectifiers provide dependable, long service under severe operating conditions. Efficiency is quite high (70%) in single phase bridge circuits and remains high with increasing load currents. Since selenium rectifiers have a threshold voltage of about 1 volt, they can not be used in extremely low-voltage applications (1 volt or less). Selenium rectifiers age during their first year in operation, resulting in about a 7% reduction in operating voltage. After this time, the voltage drop remains relatively stable.

Q. 75. Explain the action of a voltage regulator (VR) tube. 7.

A. A voltage regulator (VR) tube consists of a glass envelope filled with a gas (such as mercury vapor or argon) in which a cathode and an anode are placed. When the proper voltage is applied across the terminals, a glow discharge occurs. Operated under this condition, the VR tube maintains a constant voltage over a wide range of current. For example, an OD 3/VR150 will maintain an output voltage of 150 volts within 1.5% when the current drawn by the load varies between 5 and 40 milliamperes.

Q. 76. If the plate, or plates of a rectifier tube suddenly became red hot, what might be the cause, and how could remedies be effected? 7.

A. The plates of a rectifier tube become red hot when excessive current flows through them. This could be caused by a short in one of the filter condensers or in the plate or screen circuits that are fed by the power supply in question. In the case of a transmitter, the loss of excitation or a detuned plate tank circuit in a high power stage would also cause excessive current flow.

Q. 77. If a high vacuum type, high voltage rectifier tube should

suddenly show severe internal sparking and then fail to operate, what elements of the rectifier-filter system should be checked for possible failure before installing a new rectifier tube? 7.

A. The part most likely to cause this condition, other than the tube itself, would be one of the filter condensers.

Q. 78. What does a blue haze in the space between the filament and plate of a high vacuum rectifier tube indicate? 7.

A. A blue haze in the space between the filament and the plate indicates that the tube is gassy and is not functioning properly. There are, however, tubes in which gas is deliberately introduced. A blue haze in these tubes is normal.

INDICATING INSTRUMENTS

Q. 79. Make a sketch showing the construction of the D'Arsonval type meter and label the various parts. Draw a circuit diagram of a vacuum-tube-voltmeter and a wattmeter. 3, 4, 8.

A. The D'Arsonval type of meter movement makes use of the principle of magnetic attraction and repulsion. A coil of fine wire is suspended by two spiral springs in a magnetic field created by a permanent horseshoe magnet. A pointer is attached to the coil. If current flows through the coil, a magnetic field will be set up around the coil that will react with the field of the permanent magnet. If the current flows through the coil in the direction of the arrows, the left hand side of the coil will become a South magnetic pole and the right hand side will become a North magnetic pole. This will cause the coil to rotate in a clockwise direction (the South pole of the coil moves toward the North pole of the permanent magnet). The spiral springs at the ends of the coil tend to keep the coil from rotating too far. The magnetic reaction between the coil and the permanent magnet overcomes this resistance of the springs. If we increase the current

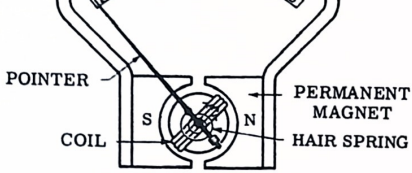


Figure 79A. The D'Arsonval type of meter movement.

through the coil, the coil will rotate more. This is due to the increased magnetic reaction between the permanent magnet and the

stronger field of the coil. When the current through the coil is removed, the two springs force the coil to return to its original position. The pointer that is attached to the coil deflects across a scale, thereby indicating relative amounts of current that flow through the movement.

The vacuum tube voltmeter (VTVM) is much more accurate than the ordinary voltmeter. This is because the VTVM has a very high input resistance and does not load down the circuit being measured.

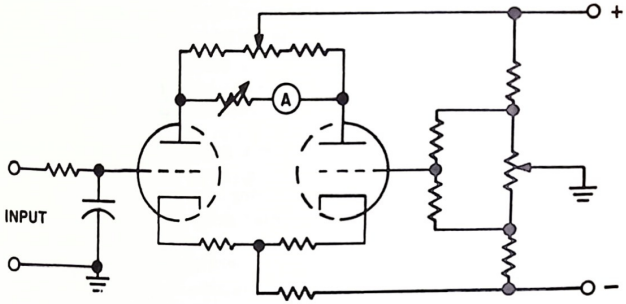


Figure 79B. A vacuum-tube-voltmeter.

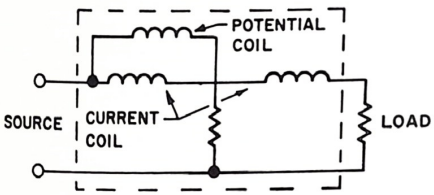


Figure 79C. A wattmeter.

Q. 80. Show by a diagram how a voltmeter and ammeter should be connected to measure power in a DC circuit. 4.

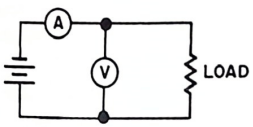


Figure 80. Measuring power in a DC circuit.

Q. 81. If a 0-1 DC milliammeter is to be converted into a voltmeter with a full scale calibration of 100 volts, what value of resistance should be connected in series with the milliammeter. 3.

A. We use Ohm's Law to find the total resistance that will provide 1 ma. when 100 volts are applied.

$$R = \frac{E}{I} = \frac{100}{.001} = 100,000 \text{ ohms.}$$

Since the milliammeter's internal resistance is very low, it can be neglected. The resistance to be added is therefore 100,000 ohms.

Q. 82. A one-milliampere meter having a resistance of 25 ohms was used to measure an unknown current by shunting the meter with a 4 ohm resistor. It then read 0.4 milliampere. What was the unknown current value? 3.

A. 2.9 ma. If .4 ma. goes through the meter, the voltage across the meter is .01V. Because the shunt is parallel to the meter, the voltage across the shunt is also .01V. From Ohm's law the current through the shunt is 2.5 ma. The total current is the sum of the currents of the meter and the shunt.

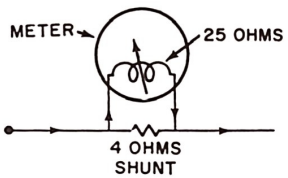


Figure 82.
A milliammeter
with a 4 ohm shunt.

Q. 83. An RF VTVM is available to locate resonance of a tunable primary tank circuit of an RF transformer. If the VTVM is measuring the voltage across the tuned secondary, how would resonance of the primary be indicated? 4.

A. The reading of the RF voltmeter as the primary circuit is tuned will depend on the degree of coupling between the two windings of the transformer. As the coupling is increased (tightened), a point is reached known as "Critical Coupling". Critical Coupling occurs when the resistance of the secondary, coupled into the primary at resonance, is equal to the primary resistance.

For values of coupling less than critical, resonance in the primary circuit will occur at the peak voltmeter reading. (See Figure 83). For values of coupling equal or greater than critical, the peak begins to flatten and as the coupling increases past the critical point, a two peak condition occurs. In this case, resonance is midway between the two peaks.

The two peak condition is sometimes called "split-tuning". If it is undesirable in a particular circuit, it can be eliminated by reducing (loosening) the coupling between the coils.

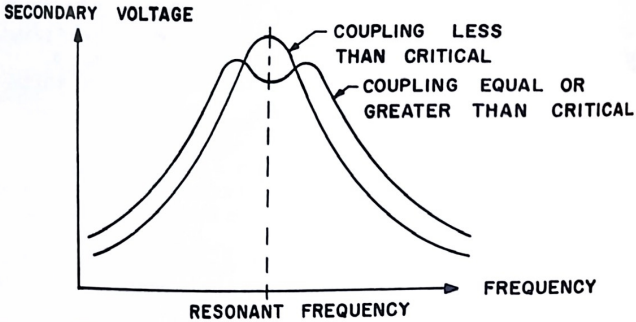


Figure 83. Voltage vs. resonant frequency curves.

Q. 84. Define the following terms and describe a practical situation in which they may be used. 2, 4.

(a) RMS voltage
(b) peak current
(c) average current
(d) power
(e) energy

A. (a) RMS Voltage means "root mean square" voltage. It is a term that is used with AC voltages. It represents the equivalent DC voltage that provides the same power over a given period of time as the AC voltage. For example, the usual AC power line voltage is 117 volts. This is the RMS voltage and delivers the same power as 117 DC volts.

The RMS voltage is equal to .707 times the peak value.

(b) Peak current. The peak current is the maximum instantaneous value of current which will occur in a circuit. A practical situation in which peak current is significant, occurs in a rectifier circuit which is immediately followed by a filter capacitor. During the first quarter cycle of operation, the capacitor is a short circuit. Consequently, the rectifier is, in effect, delivering current to a short circuit. At this moment, the rectifier must deliver peak current. Since a peak current in excess of the maximum rated peak current may destroy the rectifier, a series resistor is usually connected between the diode and the capacitor to restrict the peak current to a safe value.

(c) Average current is the average value of a current flowing through a circuit in a given direction. In the case of alternating current, the average current (or direct current) is zero amperes because the current flows first in

one direction and then the other. Since the current flows in each direction for equal times, the average over a complete alternating current cycle is zero. A practical example of average current occurs in rectifier circuits. The DC or average current delivered by a half-wave rectifier is .318 times the maximum value of the applied current.

(d) Power is the rate of energy flow. Electrical power is normally measured in watts. Since the watt is defined as 1 joule per second and the joule is a unit of energy, consequently, a watt is one joule delivered or consumed per second. The power of a transmitter is normally specified in watts.

(e) Energy is the ability to perform work. Electrical energy is the ability to perform work electrically. A capacitor is a common electrical component capable of storing energy. The energy (in joules) stored by capacitor is equal to $1/2\ CV^2$ where C is capacitance in farads and V is voltage in volts.

Q. 85. Describe how horizontal and vertical deflection takes place in a cathode ray oscilloscope. Include a discussion of the wave forms involved. 8.

A. The oscilloscope utilizes a cathode ray tube (CRT) which incorporates a pair of vertical and a pair of horizontal electrostatic deflection plates. The vertical deflection plates deflect the beam vertically while the horizontal plates provide horizontal deflection. (See Figures 85A and 85B).

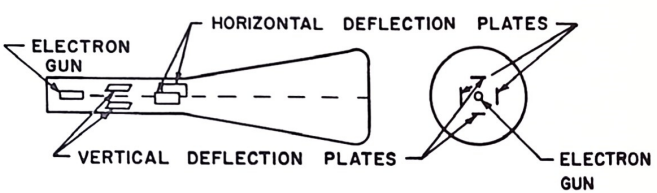


Figure 85A. Side view of cathode ray oscilloscope tube.

Figure 85B. Front or end view of cathode ray oscilloscope tube.

By changing the voltages applied to the horizontal and vertical deflection plates, the electron beam is deflected so that the trace appears on the screen of the CRT tube.

When the oscilloscope is utilized to display wave forms, a horizontal trace (also called a time base) is applied to the oscilloscope.

The purpose of the horizontal trace is to create a horizontal time scale so that time varying voltages can be displayed on the face of the CRT tube.

The horizontal trace is due to a sawtooth voltage that is applied to the horizontal plates. The saw tooth voltage is developed by a sweep generator which is an integral part of the oscilloscope.

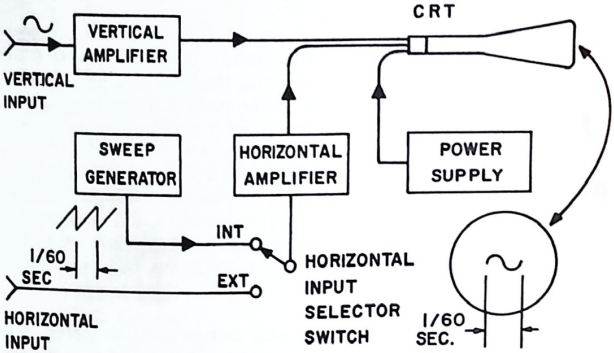


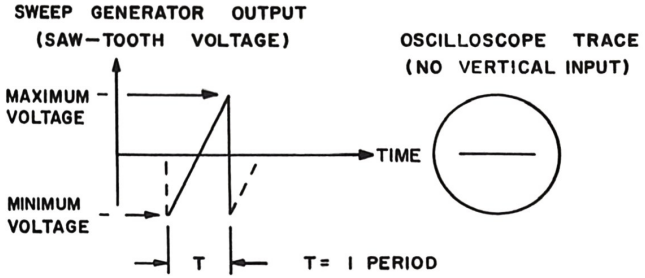
Figure 85C. Simplified block diagram of an oscilloscope.

The sawtooth voltage varies in a regular linear fashion with time as shown in Figure 85D. At the beginning, the sawtooth voltage is minimum and since the sawtooth voltage is applied to the horizontal plates, it deflects the electron beam to the extreme left of the CRT screen. As the sawtooth voltage increases to its maximum value, it moves the electron beam across the screen to the extreme right. When the beam has completed its maximum excursion to the right, the sawtooth voltage falls, almost instantaneously, to its minimum value. This return of the beam, called "retrace", repositions the beam to the left in preparation for the next sweep.

Figure 85D illustrates how the horizontal trace is developed. Note that although the electron beam is continuously sweeping left-to-right, the trace appears as a solid line (rather than as a sweeping spot). This is due to a quality of the phosphorus on the face of the screen known as "persistance". Persistance describes the ability of the phosphorus to remain illuminated a short time after the electron beam has swept by. Consequently, a horizontal line appears on the screen.

If a time-varying voltage is applied to the vertical plates of the CRT tube (via the vertical amplifier), the waveform of the voltage will be displayed on the screen of the CRT tube. If the period T of the sawtooth wave is equal to the time of one complete cycle of the time-varying signal, then one cycle of the signal will appear on the screen. For example, if, as is shown in Figure 85C, a 60 cycle voltage is

applied, then one cycle will require 1/60 of a second. Therefore, the sawtooth generator voltage should have a period of 1/60 second (T = 1/60 second).



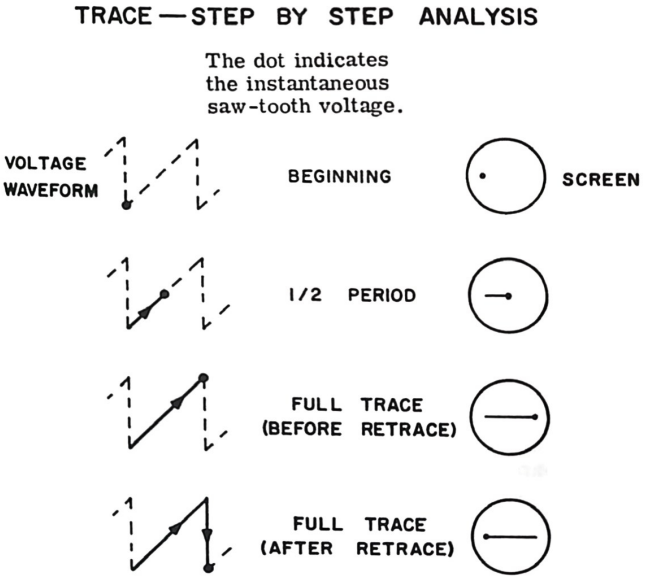


Figure 85D. Development of the Oscilloscope Horizontal Sweep.

OSCILLATORS

Q. 86. Draw circuit diagrams of each of the following types of oscillators (include any commonly associated components). Explain the principles of operation of each. 12.

(a) Armstrong
(b) Tuned plate-tuned grid (series fed and shunt fed, crystal and LC controlled)
(c) Hartley
(d) Colpitts
(e) Electron coupled
(f) Multivibrator
(g) Pierce (crystal controlled)

A. (a) Feedback is provided by coupling the plate output to the grid. This is accomplished by the magnetic coupling which exists between L_1 and L_2. The frequency is determined principally by the tuned circuit L_1, C_1. Grid-leak bias is developed by capacitor Cc and resistor Rg.

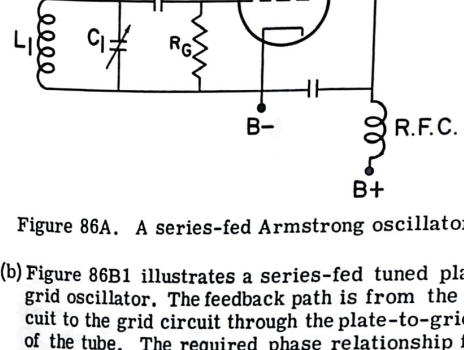


Figure 86A. A series-fed Armstrong oscillator.

(b) Figure 86B1 illustrates a series-fed tuned plate, tuned grid oscillator. The feedback path is from the plate circuit to the grid circuit through the plate-to-grid capacity of the tube. The required phase relationship for oscillation is maintained by tuning the grid tank $L_1 - C_1$ to the low side of the desired frequency and the plate tank $L_2 - C_2$ to the high side.

Bias is developed by the grid leak action of capacitor C_c and resistor R_g. The radio frequency choke, RFC, isolates the oscillator from the power supply.

Figure 86B2 illustrates a shunt-fed tuned-plate, tuned grid oscillator. Capacitor C_b prevents the B+ applied to the plate from being short circuited to ground by the plate

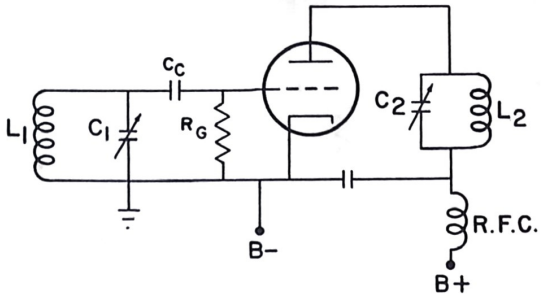


Figure 86B1. A series fed tuned plate, tuned grid oscillator.

tank coil, L2. Aside from the method of feeding the B+, this circuit operates in a manner similar to the one in Figure 86B1.

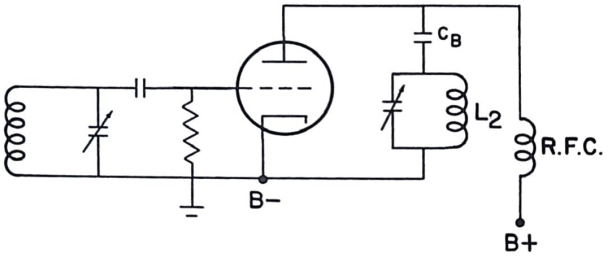


Figure 86B2. A shunt fed tuned plate, tuned grid oscillator.

Figure 86B3 illustrates a crystal-controlled oscillator with a series-fed plate supply. The crystal behaves in the same manner as the tuned circuit of Figure 86B1. When the electrical energy from the plate circuit is fed back to the grid circuit, it causes the crystal to vibrate at a frequency determined mainly by its thickness. As the crystal vibrates, it generates an electrical signal which is then fed to the grid to be amplified in the plate circuit.

(c) Figure 86C illustrates a Hartley oscillator. L_1 is connected in both the grid and the plate circuits. The portion of L_1 above the cathode tap is in the grid circuit (grid to cathode). The portion of L_1 below the

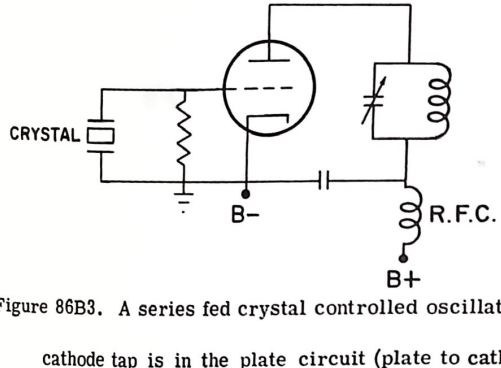


Figure 86B3. A series fed crystal controlled oscillator.

cathode tap is in the plate circuit (plate to cathode via blocking capacitor C_B). Consequently, feedback occurs due to the magnetic coupling which exists between the two parts of L_1. The frequency is determined primarily by the L_1-C_1 tank circuit. Bias is developed by the capacitor Cc-resistor Rg combination.

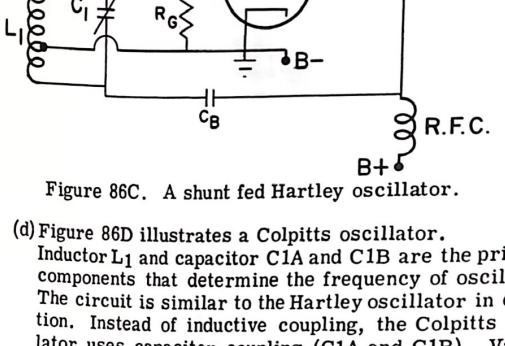


Figure 86C. A shunt fed Hartley oscillator.

(d) Figure 86D illustrates a Colpitts oscillator. Inductor L_1 and capacitor C1A and C1B are the principal components that determine the frequency of oscillation. The circuit is similar to the Hartley oscillator in operation. Instead of inductive coupling, the Colpitts oscillator uses capacitor coupling (C1A and C1B). Varying the capacitance ratio of capacitors C1A and C1B varies the feedback. Capacitor C_B is a blocking capacitor which maintains proper DC operating potentials while enabling feedback of the oscillator signal from the plate to the grid tank L1-C1A, C1B.

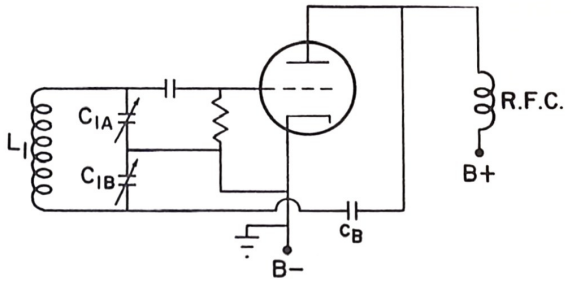


Figure 86D. A shunt fed Colpitts oscillator

(e) The electron coupled oscillator, shown in Figure 86E, has excellent frequency stability. It is virtually a Hartley circuit in which the screen functions as the plate. (See the discussion of a Hartley oscillator above). The electron coupled oscillator has several advantages over the Hartley oscillator because of the independence of the oscillator circuit from the plate of the tube. The electron coupled oscillator is relatively immune to voltage variations if the screen voltage is chosen properly. The plate tank L_2-C_2 acts as a buffer between the oscillator section and the following stage, thereby minimizing frequency changes due to loading effects. L_2 and C_2 may be tuned to some multiple of the oscillator fundamental frequency so that the one tube functions as an oscillator and a frequency multiplier.

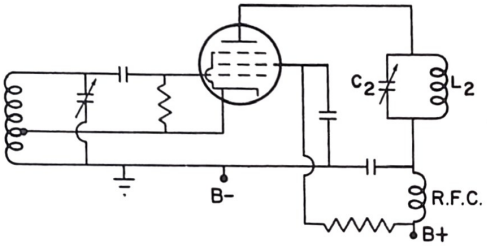


Figure 86E. An electron-coupled oscillator

(f) A multivibrator oscillator consists of two cascaded, resistance-coupled amplifiers connected so that the output of the second stage is coupled back to the input of the first stage. The two stages are identical. The output is a square wave. The frequency of the oscillator (or pulse repetition rate) is determined by the time constant of the C1-R4, C_2-R_2 combinations.

The circuit is often termed a "flip-flop" because the circuit shifts or "flips" back and forth between two states (conducting and non-conducting).

The waveform at the V2 plate of the multivibrator is shown in Fig. 86F-A. The waveform at the V1 grid is shown in Fig. 86F-B. These same waveforms appear at the V1 plate and the V2 grid, except that they are 180° out of phase. The square wave output of V2 is frequently fed to another circuit to produce a sawtooth wave shape.

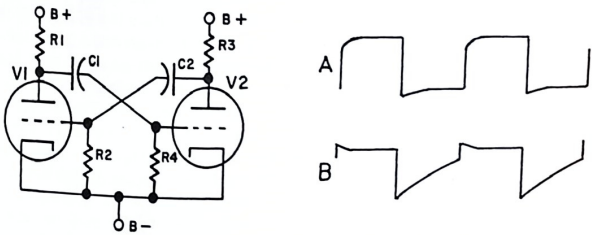


Figure 86F. A multivibrator circuit.

(g) The Pierce oscillator shown in Figure 86G can be understood by realizing that it is essentially a Colpitts circuit. The crystal is inductive at a frequency slightly higher than its series resonant mode. Therefore, it is the equivalent of L_1 in Figure 86D. The cathode-to-grid and cathode-to-plate capacitances are, in effect, C1B and C1A. The basic Pierce oscillator is novel in that it utilizes no L-C tank circuit.

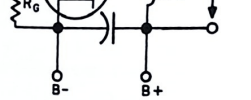


Figure 86G. A basic Pierce oscillator circuit.

Q. 87. What are the principal advantages of crystal-control over tuned circuit oscillators? 12.

A. The principal advantage of a crystal controlled oscillator over a tuned circuit oscillator is its frequency stability. Its frequency changes very little with changes in temperature and voltage. Also, crystal controlled oscillators are ideal where specific frequencies are required.

Q. 88. Why should excessive feedback be avoided in a crystal oscillator? 12.

A. Excessive feedback will overheat and possibly crack the crystal.

Q. 89. Why is a separate source of plate power desirable for a crystal oscillator stage in a radio transmitter? 13.

A. A separate power supply for the oscillator stage improves the stability of the transmitter. If the oscillator stage draws power from a power supply common to other stages, the variations and load changes of the other stages could be fed back to the oscillator through the common power supply. This would cause changes in the frequency of the oscillator.

Q. 90. What may result if a high degree of coupling exists between the plate and grid circuits of a crystal controlled oscillator? 12.

A. This would cause excessive feedback between the plate and grid circuits. The excessive feedback would overheat and possibly crack the crystal.

Q. 91. Explain some methods of determining if oscillation is occurring in an oscillator circuit. 12, 18.

A. A common method of determining if an RF oscillator is operating is to couple the output of the oscillator to an absorption wavemeter. A second method is to couple a receiver to the oscillator circuit and tune to the operating frequency; or an RF voltmeter can be coupled to the output of the oscillator to detect the signal.

In the case of audio frequency oscillator, an audio amplifier with sufficient gain can be used to detect the oscillation; or an audio voltmeter can be used.

Q. 92. What is meant by parasitic oscillations; how may they be detected and prevented? 13.

A. Parasitic oscillations are spurious signals that occur at frequencies other than the desired frequency. Parasitic oscillations in a suspected amplifier stage are detected by operating the amplifier stage without excitation. The grid and plate tuning capacitors are set to minimum value, and steps are taken to prevent plate current from exceeding the maximum rated dissipation value. If parasitic oscillation occurs, the frequency can be determined by an absorption wavemeter.

Low frequency parasitic oscillations are often caused by an inadvertent tuned-plate, tuned grid oscillator configuration which occurs in power amplifiers due principally to the presence of the grid and plate RF chokes and associated capacitances. A common corrective measure is to lower the Q of the grid RF choke with a shunting resistor. Or, the grid RF choke can be replaced by a wirewound resistor. In tetrodes, it is often necessary to increase the screen by-pass capacitance. VHF parasitic oscillations in triodes can often be eliminated by raising the resonant frequency of the neutralizing circuit leads and components.

Q. 93. What determines the fundamental frequency of a quartz crystal? 12.

A. The fundamental frequency of a quartz crystal is mainly dependent upon its thickness. It is to a lesser extent dependent upon the way in which the crystal was cut and also upon the temperature of the crystal.

Q. 94. What is meant by the temperature coefficient of a crystal? 12.

A. The temperature coefficient of a crystal indicates the temperature to frequency relationship. It tells what the variation in frequency will be with a change in temperature.

Q. 95. What are the characteristics and possible uses of an "overtone" crystal? A "third mode" crystal? 12.

A. An overtone crystal is designed to resonate at a frequency which is an approximate multiple of the fundamental frequency. The term overtone is used rather than harmonic since the crystal resonates at a frequency close to but not exactly a multiple of the fundamental frequency. Consequently, a third overtone crystal which has a fundamental frequency of 4 megacycles would have a third overtone frequency close to but not exactly 12 megacycles. An overtone crystal is characterized by decreasing activity as the overtone is increased.

A third mode crystal is a crystal which has planes so cut from the natural crystal and is so mounted that it resonates at its third mode or overtone. A third mode crystal is characterized by more complex vibrational motions than a fundamental mode crystal.

Q. 96. Explain some of the factors involved in the stability of an oscillator (both crystal and LC controlled). 12.

A. An essential factor in oscillator stability is that the frequency determining circuit LC (tank or crystal) be independent of temperature changes. Ovens or other forms of temperature stabilization are often utilized so that these critical oscillator components remain at a constant temperature.

Tube capacitances which vary with temperature play a role in frequency stability. Thus, it is wise to have the tube capacitance as

a small part of the total capacitance.

A high Q tank also improves frequency stability. Crystals are superior frequency 'tanks' since their Q is extremely high. Plate and screen voltage regulation improves frequency stability.

Buffer stages which separate the oscillator from a load reduce any effect of a changing load on the oscillator. Buffer action is an inherent part of the electron coupled oscillator.

Q. 97. Is it necessary or desirable that the surfaces of a quartz crystal be clean? If so, what cleaning agents may be used which will not adversely affect the operation of the crystal? 12.

A. The surfaces of the crystal should always be clean. The best cleaning agents are Carbon Tetrachloride or a mild-detergent soap.

Q. 98. What is the purpose of a buffer amplifier stage in a transmitter? 13.

A. The buffer amplifier stage in a transmitter tends to isolate the oscillator from the other stages in the transmitter. It thereby prevents load changes in the higher power stages from affecting the oscillator. This helps the oscillator maintain good frequency stability. The buffer also can be used as a frequency multiplier stage.

AUDIO AMPLIFIERS

Q. 99. Draw simple schematic diagrams illustrating the following types of coupling between audio amplifier stages and between a stage and a load. 9.

(a) Triode vacuum tube inductively coupled to a loudspeaker.
(b) Resistance coupling between two pentode vacuum tubes.
(c) Impedance coupling between two tetrode vacuum tubes.
(d) A method of coupling a high impedance loudspeaker to an audio-frequency amplifier tube without flow of plate current through the speaker windings, and without the use of a transformer.

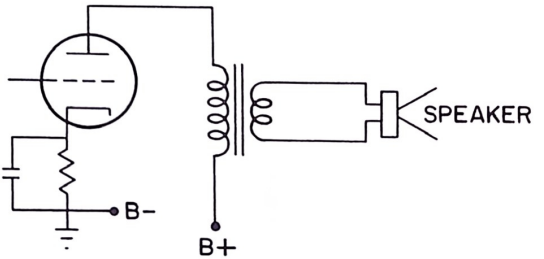


Figure 99A. A triode inductively coupled to a loudspeaker.

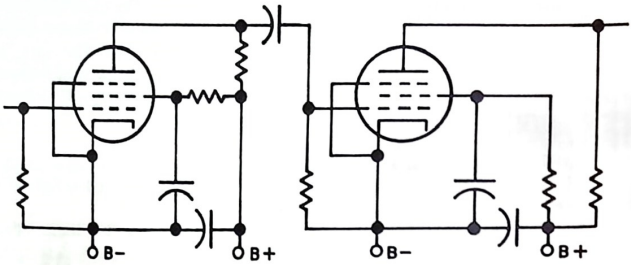


Figure 99B. Resistance coupling between two pentode tube stages.

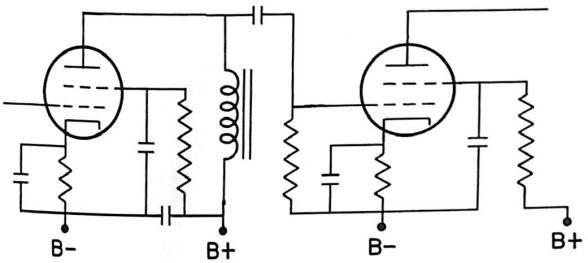


Figure 99C. Impedance coupling between two tetrode tubes.

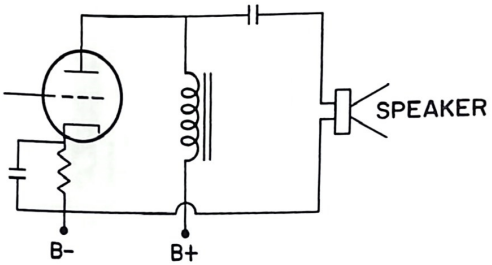


Figure 99D. A method of coupling a tube to a loudspeaker.

Q. 100. What would probably be the effect on the output amplitude and waveform if the cathode-resistor by-pass capacitor in an audio stage were removed? 9.

A. The purpose of this capacitor is to keep the cathode bias voltage constant. Removing it will introduce a degenerative effect which will reduce the output amplitude of the stage. Removing the condenser also introduces some of the distortion back to the input in such a direction that it tends to cancel itself thereby reducing some of the distortion.

Q. 101. Why do vacuum tubes produce random noise? 15.

A. The principal types of random noise produced in a vacuum tube are shot noise, partition noise and induced grid noise.

Shot noise is caused by electron bombardment of the plate. Since the electrons flow to the plate in a random fashion, a random signal or noise is generated.

Partition noise occurs in multigrid tubes. This noise is due to the arbitrary division or partition of electrons flowing to the grid and the plate. Again the division of electron flow is random so that a noise signal is produced.

Induced grid noise is created by the electrons which flow past the negatively charged control grid. Induced grid noise is frequency dependent. As the frequency is increased, the induced grid noise increases rapidly hampering effective use of the vacuum tube at the higher frequencies.

Q. 102. Why are de-coupling resistors and capacitors used in stages having a common power supply? 14.

A. The de-coupling components isolate the various stages from the power supply. They prevent feedback from occurring through a common power supply.

Q. 103. How would saturation of an output transformer create distortion? 9.

A. When saturation occurs, the transformer operates in a non-linear fashion. Consequently, it will be unable to accurately reproduce signals in the secondary winding. Hence the transformer will contribute distortion to the signal.

Q. 104. Why is noise often produced when an audio signal is distorted? 9.

A. Distortion in an audio amplifier often means that frequencies not present in the original signal are generated. These signals occurring at random frequencies produce noise.

Q. 105. What are the factors which determine the correct bias voltage for the grid of a vacuum tube? 9.

A. The principal factor which determines the grid bias voltage

for a vacuum tube is the class of service that is desired. Classes A, AB, B and C each require different bias voltages. Other factors determining the choice of grid bias include power output, permissible plate and grid dissipation and permissible distortion.

Q. 106. Draw schematic diagrams illustrating the following types of grid biasing and explain their operation. 9.

(a) Battery
(b) Power Supply
(c) Voltage divider
(d) Cathode-resistor

A. (a) Grid bias is the negative voltage that is applied to the grid with respect to the cathode. The positive side of the "C" battery is connected to the cathode. The negative side is connected to the grid through the grid coil. Thus, the "C" battery provides the grid bias for this tube.

(b) Figure 106B illustrates the use of power supply bias. In some equipment where large power tubes are used, a separate bias power supply is required. The negative terminal of the bias supply is connected to the grid (through a coil in Fig. 106B) and the positive side is connected to the cathode, thereby making the grid negative with respect to the cathode.

(c) Figure 106C illustrates a voltage-divider method of obtaining bias. R1 and R2 are across the "C" bias supply. They form a voltage divider. The voltage drop across R2 is applied between the grid and cathode, the negative side going to the grid and the positive side to the cathode.

(d) Figure 106D shows the common type of cathode-resistor bias. The plate current flowing through the cathode resistor, R, causes a voltage drop across R. The bottom of R is negative with respect to the top. Since the top is connected to the cathode and the bottom is connected to the control grid (through the grid resistor), the grid becomes biased negative with respect to the cathode.

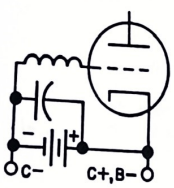


Figure 106A. Battery bias.

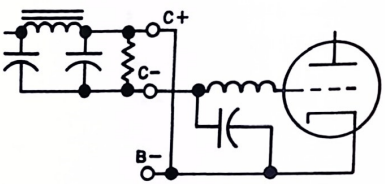


Figure 106B. Power supply bias

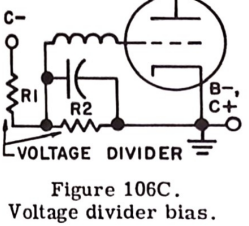


Figure 106C.
Voltage divider bias.

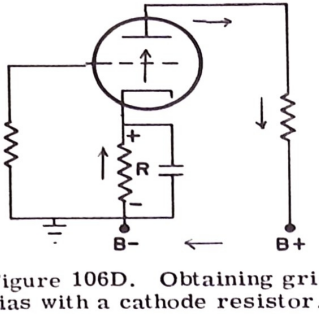


Figure 106D. Obtaining grid bias with a cathode resistor.

13.

Q. 107. Is grid-leak biasing practical in audio amplifier stages?

A. Grid-leak biasing is not practical in an audio amplifier because this type of biasing requires the grid to be driven into the positive voltage region. When the grid of the tube becomes positive, the input impedance of the tube suddenly changes from a very high value to a very low value. This changing input impedance would introduce considerable distortion.

In addition, when the grid becomes positive, the amplification factor (μ) of the tube is likely to change considerably because of saturation.

Q. 108. Draw a diagram showing a method of obtaining grid bias for a filament type vacuum tube by use of resistance in the plate circuit of the tube. 9.

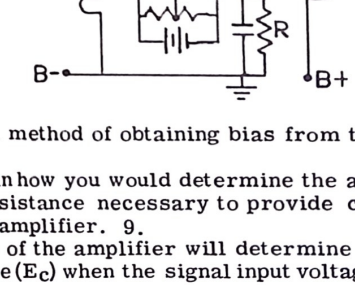


Figure 108. A method of obtaining bias from the plate current.

Q. 109. Explain how you would determine the approximate value of cathode bias resistance necessary to provide correct grid bias for any particular amplifier. 9.

A. The design of the amplifier will determine the plate current (i_b) and grid voltage (E_c) when the signal input voltage is zero. These

zero signal input values are termed "quiescent values". The cathode resistor (Rk) is computed as follows:

$$Rk = \frac{E_c}{i_b}$$

Where: E_c = quiescent grid voltage
i_b = quiescent plate current
Rk = cathode resistance

Q. 110. Draw circuit diagrams and explain the operation (including input-output phase relationships, approximate practical voltage gain, approximate stage efficiency, uses, advantages and limitations) of each of the following types of audio circuits. 9.

(a) Class A amplifier with cathode resistor biasing.
(b) Cathode follower amplifier.
(c) At least two types of phase inverters for feeding push-pull amplifiers.
(d) Cascaded Class A stages with a form of current feedback.
(e) Two Class A amplifiers operated in parallel.
(f) Class A push-pull amplifier.

A. (a) A circuit diagram for a Class A amplifier with cathode biasing is shown in Figure 110A. Grid bias is developed by the flow of cathode current through resistor Rk. This means that the cathode is at a positive potential with respect to ground. When the input signal is zero volts, then the grid is at the same potential as ground; or in other words, negative with respect to the cathode.

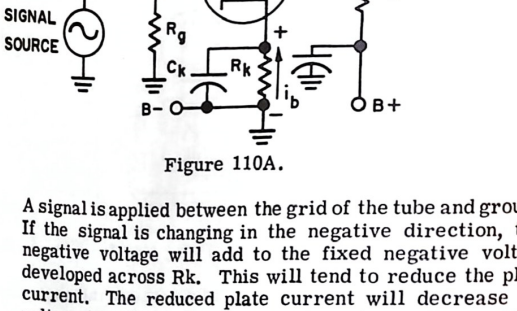


Figure 110A.

A signal is applied between the grid of the tube and ground. If the signal is changing in the negative direction, this negative voltage will add to the fixed negative voltage developed across Rk. This will tend to reduce the plate current. The reduced plate current will decrease the voltage drop through R_L raising the output voltage. When the signal voltage excursion is increasing, the grid will become more positive. The plate current flow and consequently the voltage drop across resistor R_L will increase. Therefore, the output voltage will decrease.

Consequently, the amplifier reverses the phase of the signal so that a 180 degree phase shift occurs. To ensure Class A operation, the grid voltage swing must be small enough so that neither cut-off nor saturation occurs. The approximate voltage gain of the triode amplifier is given in the following relationship:

$$A = \frac{\mu R_L}{R_P + R_L}$$

Where: μ is the amplification factor of the tube
R_L is the load into which the tube is operating
R_P is the plate resistance of the tube

The Class A amplifier is used primarily as a voltage amplifier in the audio frequency range. The distortion is low because no grid current is drawn by the tube and plate current flows at all times. Because the plate current flows during the entire cycle, the efficiency of a Class A amplifier is low compared to the other classes of amplification.

(b) A circuit of a cathode follower amplifier is shown in Figure 110B. The significant feature of the cathode follower is that the output is obtained at the cathode of the tube. The term "cathode follower" comes from the fact that the output follows the input voltage. The reason for this is as follows: When the signal applied to the input goes positive, the plate current, which flows through the cathode resistor, increases. This increases the voltage across Rk and consequently, the output increases. This means that the output is in phase with the input voltage.

Since the voltage gain of the cathode follower is slightly less than one, the cathode follower has no value as a voltage amplifier. The value of this circuit lies in its excellent frequency response. In fact, for certain tubes, the frequency response is excellent up to 200 megacycles. It is often used in video and oscilloscope circuits.

Moreover, the cathode follower circuit has a high input impedance and a low output impedance. It is, therefore

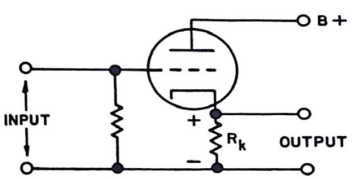


Figure 110B. A cathode follower amplifier.

useful as an impedance transformer. The power gain of the cathode follower is equal to the ratio of the output resistance to the input resistance.

(c) One type of phase inverter is called a split load phase inverter. It is a relatively simple phase inverter. Its circuit is shown in Figure 110C1. Note that a signal applied between the grid and the ground appears as two signals - one at the plate and one at the cathode. The coupling capacitors, Cc, enable the signals to be connected to the grids of the push-pull stage without disturbing the plate and cathode voltages of the phase inverter tube. To understand why the signals are out of phase, consider each output signal independently. The signal to be applied to grid No. 1 of the following tube is supplied from the plate of the phase inverter tube. If we ignore for a moment the Cc capacitor to grid No. 2, then this circuit is the same as a conventional grounded cathode stage without a cathode bias capacitor. Consequently, the output from the plate is out of phase with the input. On the other hand, if we ignore the Cc coupling capacitor to grid No. 1, then the circuit corresponds to a cathode follower circuit. Since the output of a cathode follower is in phase with the input, the output to grid No. 2 is out of phase with the output to grid No. 1. Thus, the phase requirement for the input to a push-pull amplifier is met. The gain at each output is about the same as a cathode follower - slightly less than one. The principal disadvantage to this circuit is that the output impedance to grid No. 1 is considerably higher than the output impedance to grid No. 2.

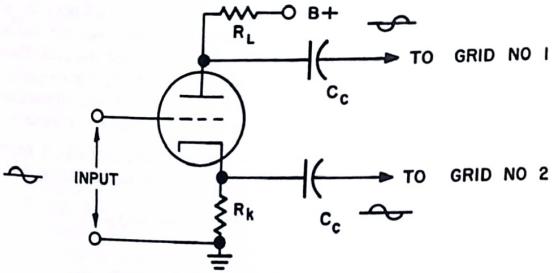


Figure 110C1. Split load phase inverter.

The circuit shown in Figure 110C2 is somewhat more complex than the split load phase inverter discussed above. However, it has the advantage of presenting equal output impedances to each of the grids of the following

push-pull stage. The output to grid No. 1 can actually be thought of as the output from a grounded cathode amplifier. Thus this output is out of phase with the input. The output at grid No. 2 is in phase with the input. To understand why this is true, note that V1 and V2 are, in effect, two cascaded amplifier stages. The output at the cathode of V1 is in phase with the input. (The tube can be thought of as a cathode follower). The in-phase output voltage from V1 is applied to the cathode of V2. (Note that V2 is operated in a grounded-grid configuration). Since the output of a grounded-grid stage is in phase with the input, the in-phase voltage at the cathode of V2 appears again as an in-phase voltage at the plate of V2.

The gain of each output relative to the input is equal to about one-half the gain of a tube operated in a single tube grounded cathode configuration.

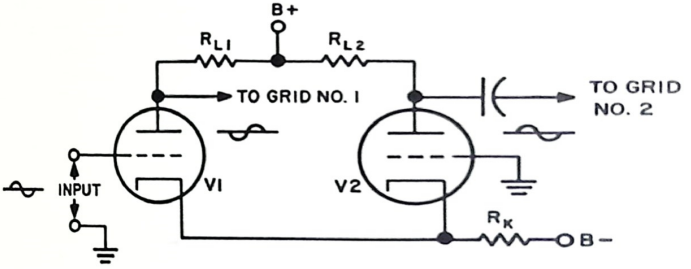


Figure 110C2. A cathode coupled phase inverter.

(d) A diagram of a two-stage cascaded amplifier with current feedback is shown in Figure 110D. Since the two stages are operated in a grounded cathode configuration, each stage provides a 180 degree phase reversal. As a consequence, the output from V2 is in phase with the input to V1.

Note that the output current flows through Cc, the output load and finally through resistor Rk in the first amplifier stage. This current flow through Rk produces a voltage labeled E_{fb} in the diagram. The phase of the voltage is out of phase with the input signal, hence it is negative feedback.

Current feedback improves the capability of the amplifier to develop an output current with minimum distortion. The cascaded amplifier with current feedback is often used in cathode ray tube deflection circuits.

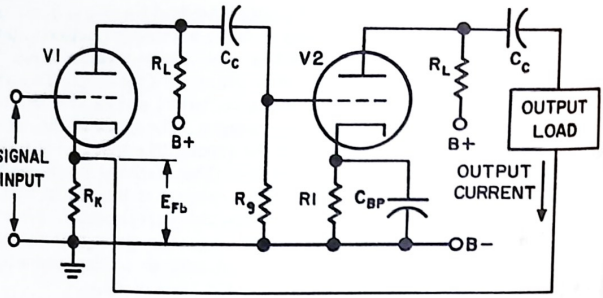


Figure 110D. Two Class A stages in cascade.

(e) A circuit diagram showing two triode vacuum tubes operating in parallel is shown in Figure 110E. Note that the plates, cathodes and grids of both tubes are connected together. This circuit is no different in operation than the single Class A amplifier tube discussed in Q110A. However, this circuit will essentially double the power capability of a single tube.

Since the two tubes are connected in parallel, the output impedance of the circuit will be one-half the output impedance of the single tube. Since the output transformer shown in Figure 110E serves as an impedance match between the two tubes and the loudspeaker, it must be chosen accordingly. The cathode resistor Rk must be one-half the resistance required by the single tube since the cathode current for both tubes flows through it. Because a Class A amplifier requires no driving power (no grid current flows), no changes will be required in the input signal. However, the high frequency response will be

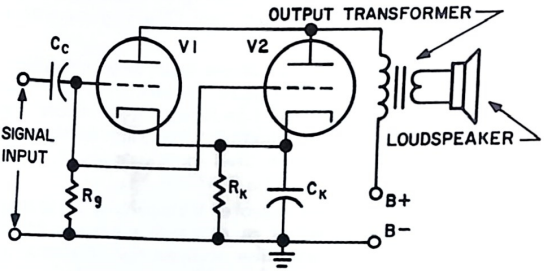


Figure 110E. Two triode vacuum tubes operated in parallel.

poorer than a single tube since the tube's interelectrode capacitances will be in parallel. These capacitances shunt both the input and the output of the circuit and, therefore, reduce the gain of the amplifier at high frequencies.

The parallel Class A amplifier is used where power rather than high fidelity is the prime requirement.

(f) A diagram of two vacuum tubes connected as a push-pull Class A amplifier is shown in Figure 110F.

Two input signals are required. They must be identical in magnitude but 180° out-of-phase with each other. The signals can be developed by phase inverters (refer to Question 110C) or by a center-tapped driver transformer. These input signals drive the grid of one tube positive while the grid of the second tube is being driven negative. Thus, as the plate of one tube is going more negative, the plate of the second tube is going more positive. The output voltages of the two tubes add in the output transformer. The transformer couples this output voltage to the loudspeaker.

Proper push-pull operation requires that the two tubes be as identical as possible. If this condition can be met, then the circuit will have several advantages over a 'single-ended' configuration. (Refer to Questions 110A and 110E).

First, a push-pull circuit cancels out the even-order harmonics so that distortion is much lower than in the single-ended configuration. Secondly, note that the plate current in each tube (labeled I_{b1} and I_{b2} in Figure 110F) flow in opposite directions in the primary winding of the output transformer. This means that any ripple voltage coming from the plate power supply will flow in opposite

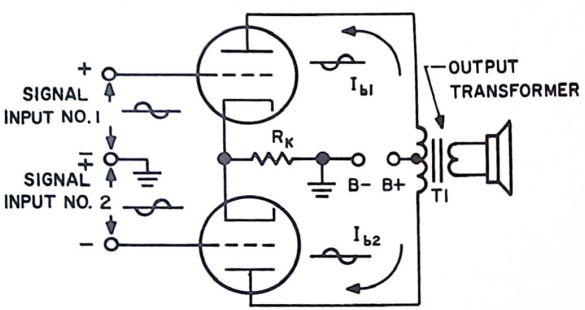


Figure 110F. Class A push-pull amplifier

directions in the primary and thus, will cancel. Furthermore, since the DC currents are flowing in opposite directions in the primary, core saturation which causes distortion will not occur.

The plate efficiency of push-pull Class A amplifiers is the same as for a single Class A amplifier. Push-pull amplifiers are seldom operated in Class A since plate efficiency and power output are quite low. Class AB and Class B operation are more common modes of push-pull operation.

Q. 111. Why does a Class B audio frequency amplifier stage require considerably greater driving power than a Class A amplifier?

A. In the case of a Class A amplifier, the grids are always negative and never draw any grid current. However, in a Class B amplifier, the grids are driven positive during a part of the cycle and draw current. This loads the previous stage (driver stage) which must supply this power.

Q. 112. Show by use of circuit diagrams, two ways of using single-ended stages to drive a push-pull output stage. 9.

A. Figure 112 illustrates a common method of feeding a push-pull stage with a single tube. A transformer with a center tapped secondary is used. The ends of the transformer secondary are opposite in phase, thereby meeting the basic requirement of the push-pull stage. Another single-ended stage that can be used to drive a push-pull amplifier is shown in Figure 110C1.

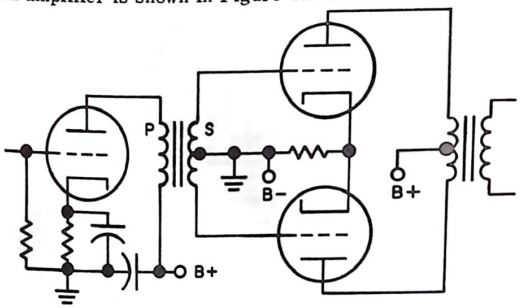


Figure 112. A single tube driving a push-pull stage.

Q. 113. Draw circuit diagrams and explain the operation of two commonly used tone control circuits and explain their operation. 9.

A. Figure 113A illustrates a simple tone control circuit commonly employed in inexpensive receivers. The capacitor C1 acts as a short-circuit at the higher frequencies. Hence the circuit is a

"treble attenuator". Maximum attenuation occurs when the slider of resistor R1 is positioned to short circuit R1, thereby connecting C1 directly to ground.

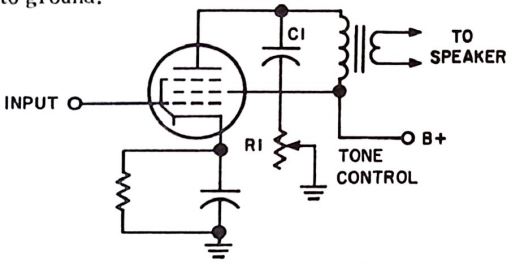


Figure 113A. A simple method of tone control.

Figure 113B illustrates bass and treble control circuits which provide independent control of the treble and bass response of the amplifier. The operation can be understood by examining the equivalent circuits. Here the circuits are redrawn with the potentiometers

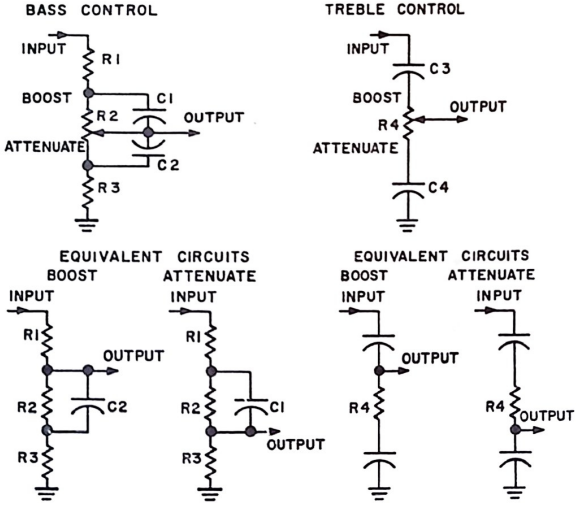


Figure 113B. Base and treble tone controls with their equivalent circuits.

fully clockwise or counterclockwise. Recalling that a capacitor is a short circuit at high frequencies and an open circuit at low frequencies, the circuits can then be visualized with the capacitors open-circuited (low frequencies) or short circuited (high frequencies). Hence, each circuit becomes a simple resistor voltage divider.

Q. 114. Name some causes of hum and self-oscillation in audio amplifiers and the methods of reducing it. 9.

A. Causes of hum and self-oscillation, as well as methods for reduction, are listed below:

HUM

Cause	Remedy
Poor Power Supply Poor filtering allows excessive AC ripple to be delivered by the DC power supply to the amplifier.	Redesign of the power supply filter to reduce the AC ripple. This may require larger capacitors and inductors or a different filter circuit.
Pickup of stray signals by high gain amplifier stages.	More effective shielding of leads, particularly grid leads. Shielding of glass vacuum tubes. Re-orient transformers so that they no longer induce fields in the vicinity of high gain stages.
Modulation of the audio signal by an AC operated filament.	Balance the filament to ground either by using a center-tapped filament transformer or by incorporating a center-tapped resistor. Operate the filaments from a DC supply.

SELF-OSCILLATION

'Motorboating' caused by feed-back of the signal to the input stages via stray lead capacitance.	Shield leads. Re-orient leads so they do not provide a path from the output of a stage to its input.
Motorboating caused by a feedback path via a common B+ power supply.	'Decouple' the B+ supply by incorporating decoupling resistors and by-pass capacitors in the plate supply.

Q. 115. What factors should be taken into consideration when ordering a Class A audio output transformer; a Class B audio output transformer feeding a speaker of known ohmic value? 9.

A. The following are important factors to consider when choosing an output transformer:

(a) Impedance Match. The output transformer should have the proper turns ratio to provide an impedance match between the vacuum tubes (or transistors) and the speaker.

(b) Power Rating. The transformer must be capable of carrying the power without overheating. For a given output power rating, Class A operation will require a transformer with greater power handling capabilities than will Class B operation. The reason is that plate current flows at all times in the Class A amplifier, whereas plate current flows in Class B operation only when a signal is being amplified.

Low winding resistance and thin core laminations contribute to low power dissipation in a transformer.

(c) Frequency Response. If wide frequency response is required, then a transformer with good response characteristics over the required frequencies should be selected.

Q. 116. Draw a diagram of a single-button carbon microphone circuit, including the microphone transformer and source of power. 11.

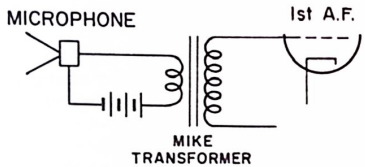


Figure 116. A carbon microphone hookup.

Q. 117. If low impedance head telephones of the order of 75 ohms are to be connected to the output of a vacuum tube amplifier, how may this be done to permit most satisfactory operation? 9.

A. The head telephones can be coupled to the vacuum tube amplifier by means of an audio transformer. The audio transformer provides an impedance match between the vacuum tube amplifier and the head telephones. Proper impedance match assures that maximum power is transferred to the head telephones and provides a proper load for the vacuum tube.

Q. 118. Describe the construction and explain the operation of a "crystal" type microphone. A "carbon button" microphone. 11.

A. The active element in a crystal microphone is a crystalline material, usually Rochelle salts. Other crystals that may be used are Quartz and Tourmaline. These crystals exhibit the piezo-electric effect, that is, they develop a voltage when mechanical pressure is applied to them. Sound vibrations applied to a crystal microphone develop a voltage whose frequency varies in accordance with the frequency of the applied sound. This voltage is applied to an audio amplifier.

The crystal microphone has the following characteristics:

1. Its response is flat over the entire audio range.

2. Its output can be applied to the grid of an audio amplifier without the use of a power supply or transformer.

The "carbon button" type microphone consists of a small container (button) filled with fine granules of carbon, attached to a tight diaphragm. Sound vibrations striking the diaphragm cause varying pressures upon the button, thus causing varying resistances across the microphone. Because of a small battery in series with the microphone, these varying resistances cause corresponding variations in the button's output current; variations that are in accordance with the sound waves that produce them.

The frequency response of a carbon button type microphone is more limited than that of the crystal type microphone. Although one of the characteristics of the carbon button microphone is very high sensitivity, it has serious drawbacks; it requires a power supply, it is sensitive to vibration and handling, and it is subject to "packing" of the carbon granules.

Q. 119. What precaution should be observed when using and storing crystal microphones? 11.

A. The crystal microphone should NOT be subjected to any of the following: moisture, large temperature changes (especially high temperatures), physical shock or rough handling.

Q. 120. What is an RFC? Why are they used? 4.

A. RFC stands for radio frequency choke. They are used to oppose or resist radio frequency currents while allowing DC to pass through.

Q. 121. What are the advantages of using a resistor in series with the cathode of a Class C radio frequency amplifier tube to provide bias? 13.

A. The advantages of using a resistor in series with the cathode is that a bias power supply is dispensed with.

The grid bias resistor also provides protective bias. If excitation to the Class C stage fails, the plate current flow will continue to develop sufficient grid bias to prevent excessive plate current to flow.

Q. 122. What is the difference between RF voltage amplifiers and RF power amplifiers in regards to applied bias? What type tube is generally employed in RF voltage amplifiers? 13, 14.

A. When a tube is used as an RF voltage amplifier, a grid bias voltage is chosen so that the plate current flows at all times. By contrast, RF power amplifiers are biased at a grid voltage more negative than cut-off. Plate current flows for one-half of a cycle or less, and during the remaining portion of the cycle, the tube is cut-off. RF voltage amplifiers usually employ variable-mu pentodes.

Q. 123. Draw schematic diagrams of the following circuits and give some possible reasons for their use. 13.

(a) Link coupling between a final RF stage and an antenna. (Include a low pass filter).

(b) Capacitive coupling between an oscillator stage and a buffer amplifier.

(c) A method of coupling a final stage to a quarter-wave Marconi antenna other than link or transmission line.

A. (a) Link coupling provides an ideal means of coupling energy from the plate tank circuit to the antenna where the two circuits are to be physically located some distance from each other (Figure 123A). In addition, link coupling in conjunction with the low pass filter reduces the amount of unwanted harmonic energy from reaching the antenna.

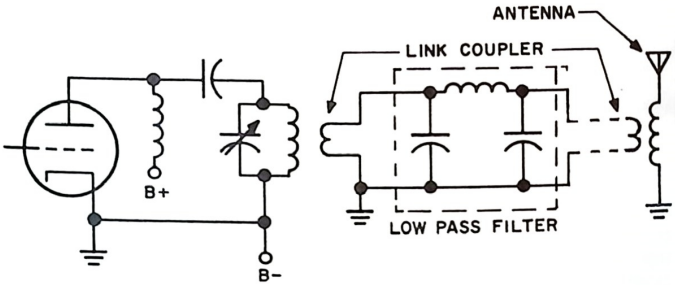


Figure 123A. Link coupling between final amplifier and antenna.

(b) Capacitive coupling is often used because of its simplicity. Tuned circuits are avoided and hence, if the frequency is changed, no tuning is required in the coupling circuit. See Figure 123B.

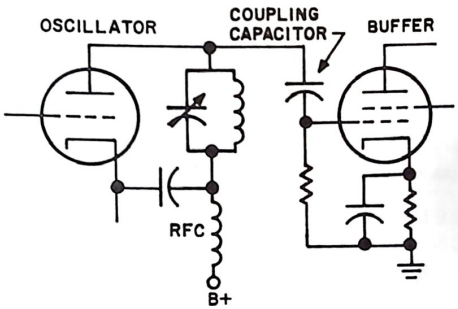


Figure 123B. Capacitor coupling between oscillator and buffer stages.

(c) Figure 123C illustrates a pi-network coupling circuit. Loading is accomplished by varying C_L. Tuning is mainly performed by C_T and L_1. C_L will affect the tuning to some extent. The pi-network offers good harmonic attenuation and has the capability of matching a wide range of antenna impedances.

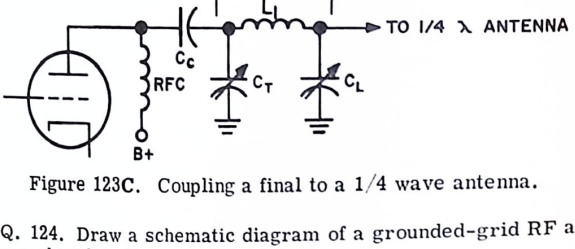


Figure 123C. Coupling a final to a 1/4 wave antenna.

Q. 124. Draw a schematic diagram of a grounded-grid RF amplifier and explain its operation. 13.

A. The grounded grid amplifier operates in much the same manner as the common grounded cathode amplifier. The grid, which is grounded, is biased negatively with respect to the cathode. The input signal is applied to the cathode circuit (between cathode and grid). This causes the plate current to vary and the amplifier output is taken between the plate and grid.

Grounded grid amplifiers are very stable and do not require neutralization. The grounded grid circuit reduces the output-to-input (plate to cathode) capacity considerably and makes oscillation almost impossible.

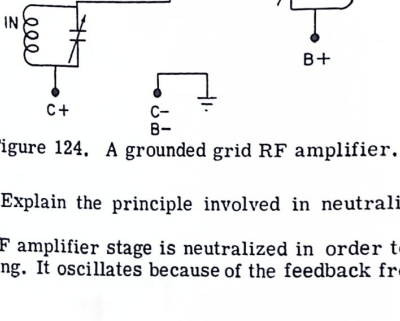


Figure 124. A grounded grid RF amplifier.

Q. 125. Explain the principle involved in neutralizing an RF stage. 13.

A. An RF amplifier stage is neutralized in order to prevent it from oscillating. It oscillates because of the feedback from the plate

circuit to the grid circuit through the plate-to-grid capacitance of the tube. All triode RF stages and some high frequency tetrode and pentode amplifier stages have to be neutralized.

All neutralization methods utilize the principle of cancelling out or neutralizing the feedback that normally occurs. This is done by connecting an external condenser into the circuit in such a way that a voltage is fed back from the plate circuit to the grid circuit. This voltage is fed back 180° out of phase with the voltage that is fed back through the grid-to-plate capacity of the tube. The size of the external capacitor is such that the voltage fed back by the neutralizing capacitor is equal to the voltage fed back through the grid-to-plate capacity. Since the two voltages are equal and opposite to each other, cancellation takes place and oscillation is thus prevented.

Q. 126. State some indications of, and methods of testing for, the presence of parasitic oscillations in a transmitter. 13.

A. See Question 92.

Q. 127. Draw a circuit diagram of a push-pull (triode) final power amplifier, with transmission line feed to a shunt fed quarter wave antenna and indicate a method of plate neutralization. 13.

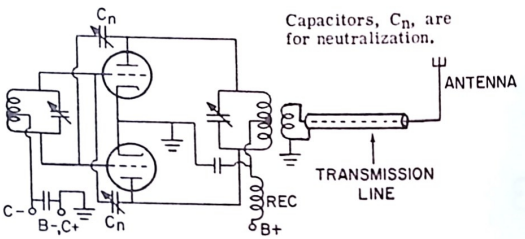


Figure 127. A push-pull amplifier coupled to an antenna.

Q. 128. Explain, step-by-step, at least one procedure for neutralizing an RF amplifier stage. 13.

A. A common procedure for neutralizing an RF amplifier is as follows:

(1) Remove the plate voltage from the stage to be neutralized. This is very important since it is impossible to neutralize an amplifier with the plate voltage applied.

(2) The stage preceding the stage to be neutralized should have its power on and should be properly tuned. The filament voltage of the stage being neutralized should be on.

(3) The grid and plate tank circuits of the stage being neutralized should now be tuned to resonate with the signal coming from the preceding stage. This is done by tuning the grid and plate tank

condensers for a maximum indication of the RF indicator which is coupled to the plate tank circuit. The RF indicator may be a neon bulb or a flashlight bulb connected to a small loop of wire. We can also use a thermocouple ammeter which is connected in series with the plate tank circuit. If a thermocouple ammeter is used, care should be taken not to overload the meter. It is a sensitive instrument that is easily damaged. Any coupling between an indicating instrument and plate tank coil should be made as loose as possible.

(4) The neutralizing condenser or condensers are then adjusted until the RF indicator shows that the RF energy in the plate tank circuit is at a minimum.

(5) Repeat steps 3 and 4 to make sure that the stage is as completely neutralized as possible.

Q. 129. Draw a circuit diagram of a "push-push" frequency multiplier and explain its principle of operation. 13.

A. Figure 129 illustrates a "push-push" frequency multiplier. Note that the grids are connected in push-pull while the plates are connected in parallel. Whereas the normal push-pull amplifier will cancel even harmonics, the push-push amplifier works well at even harmonic frequencies. The efficiency of a push-push doubler is almost as good as that of a single-ended RF amplifier. This is because there is a plate current pulse for each cycle of output frequency.

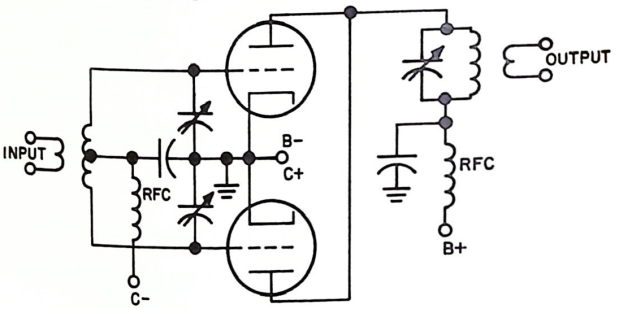


Figure 129. A push-push frequency multiplier.

Q. 130. Push-pull frequency multipliers normally produce what order of harmonics; even or odd? 13.

A. Push-pull frequency multipliers normally produce odd harmonics.

Q. 131. Draw a schematic diagram and explain the operation of a harmonic generator stage. 13.

A. Figure 131 illustrates a frequency doubler. A frequency doubler is a Class C amplifier with a very high value of bias. The plate tank circuit is tuned to twice the frequency of the grid tank cir-

cuit. The Class C amplifier introduces considerable harmonic distortion. Since the plate circuit is tuned for the second harmonic, the second harmonic (twice the input signal frequency) becomes the output frequency.

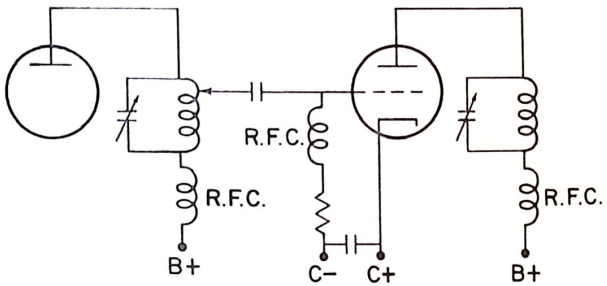


Figure 131. A harmonic generator stage.

Q. 132. What class of amplifier is appropriate to use in a radio-frequency doubler stage? 13.

A. A Class C amplifier should be used as a radio-frequency doubler stage.

Q. 133. Describe some factors in connection with the following items, which should be considered at VHF and above, but would not be of particular concern at MF or below. 19.

(a) Wire diameter and lead length.
(b) Wiring configuration (placement and bending).
(c) Coaxial cables and transmission lines.
(d) Capacitor types.

A. (a) Wire diameter and lead length. Lead inductance is a critical factor at VHF frequencies, since inductors offer increasing impedance as the frequency rises. To hold lead inductance to the minimum, large diameter, short leads should be used. The use of multiple parallel leads can further reduce lead inductance.

(b) Wire configuration (placement and bending). Wires must be placed so that interaction with other circuits is negligible. If a wire passes close to another wire, the inter-wiring capacitance may impair circuit functioning. At high frequencies, most of the current travels along the surface of the wire. This phenomenon is called "skin effect". Sharp bends should be avoided since the current travelling on the wire surface tends to concentrate in the sharp corners. This upsets symmetrical current flow, thereby increasing radiation losses.

(c) Coaxial cables and transmission lines. Two types of losses are significant when transmission lines are utilized at VHF frequencies: radiation and dielectric losses.

Radiation losses can be thought of as the degree to which a line acts as an antenna. Parallel transmission lines should be closely spaced to minimize radiation loss. Coaxial cable has almost no radiation loss since the electromagnetic field is confined almost entirely within the shield.

Dielectric losses result from minute currents flowing through the insulating material (dielectric) which separates the two conductors. Coaxial cable exhibits the lowest losses when an inert gas dielectric is used. However, this dielectric is impractical and costly. Polyethelene and Teflon are more common. In general, the larger diameter coaxial cables have lower line loss.

Parallel transmission lines are often constructed by separating the leads with polyethylene spacers at intervals along the line. This type of transmission line, also called "open-wire line", has less dielectric loss than the more common twinlead employing polyethylene dielectric.

(d) Capacitor types. Capacitors which are to be used for by-passing must offer an extremely low impedance to ground. The principal problem at VHF frequencies is lead inductance which impairs the ability of a capacitor to "by-pass". However, whereas paper and even ceramic capacitors have considerable lead inductance, the button mica and the bulkhead mounting ceramic types have negligible lead inductances. These types should be used for effective by-passing at high frequencies.

A variable capacitor which is part of a tuned L-C circuit can often be replaced by a "Butterfly-type" capacitor. This capacitor incorporates the inductor so that lead inductance is virtually nonexistent.

Q. 134. Discuss the following items with respect to their harmonic attenuation properties as possibly used in a transmitter or receiver. 13.

(a) Link coupling
(b) Tuned circuits
(c) Degree of coupling
(d) Bias voltage
(e) Decoupling circuits
(f) Shielding

A. (a) Link coupling. When a link is added to a tuned L-C circuit, a transformer is formed. A high degree of harmonic attenuation results because the majority of the energy transfer will be due to magnetic coupling at the resonant frequency of the L-C circuit. However, a certain amount of energy transfer will occur due to capacitive-coupling between the windings. Since a capacitor offers a decreasing impedance at higher frequencies, a certain amount of energy transfer will occur due to this capacitive effect. Capacitive coupling can be greatly reduced by incorporating a Faraday shield between the two windings.

(b) Tuned circuits. Tuned circuits are more effective at harmonic attenuation than capacitive coupling circuits due to their frequency selecting characteristics. High - Q circuits with their steep-sided response curves offer high attenuation to harmonics.

Double-tuned circuits are more effective than single-tuned circuits.

(c) Degree of coupling. Tuned transformers with a low degree of coupling have a narrower bandpass and hence, greater harmonic attenuation than transformers with higher coupling.

(d) Bias voltage. High bias voltage increases the overall harmonic output of an amplifier. Consequently, bias voltages should be as low as possible for best harmonic attenuation. However, this is not necessarily true for any specific harmonic. For example, the third harmonic might be attenuated by some value of grid bias at the expense of overall harmonic attenuation.

(e) Decoupling circuits. Decoupling circuits usually take the form of low pass filters incorporating shunting capacitors and series inductors. Capacitors with negligible series inductance are necessary if effective high frequency attenuation is to be achieved. Both coaxial and button-type capacitors have low series inductance and are, therefore, preferable to the tubular or disc type capacitor.

(f) Shielding. Shielding prevents radiation from occurring. It can be in the form of shield partitions, shielded enclosures or shielded wire. The crucial factor with shields pertains to the passage of wires through the shield. This must be done in such a manner that harmonic energy is not inadvertently passed through the shield. Consequently, decoupling circuits (discussed in (e)) are employed at the shield entrance.

Q. 135. Define "transmitter intermodulation", a possible cause (or causes), its effects and steps that could be taken to reduce it. 14

A. "Transmitter Intermodulation" refers to spurious signals that are generated within linear RF amplifiers due to non-linearity.

A voice signal can be thought of as a large number of independent signals which occur at specific frequencies. If a voice modulated RF signal were amplified in a perfectly linear RF amplifier, only the amplified signals containing the input frequencies would be present at the output. However, since no amplifier is perfectly linear, the signals at the various frequencies will mix (or intermodulate) generating intermodulation products. Some of these intermodulation products, the so-called "odd-order products", will be amplified along with the original voice signal causing distortion. This distortion causes splatter which, in turn, can cause adjacent channel interference. In general, transmitter intermodulation is reduced by operating the transmitter in as linear a fashion as possible. This means that all stages up to the final power stage should operate Class A. The operating point of the power stage should be so chosen so that maximum linearity is achieved. In addition, RF feedback can be employed to further improve linearity.

Q. 136. State a probable cause of and method of reducing transmitter spurious emissions (other than harmonics). 13.

A. Two common causes of spurious emissions in transmitters are self-oscillation and parasitic oscillations.

Self-Oscillation is prevented in triode and in some multi-grid amplifiers (tetrodes, pentodes) by neutralization. Isolation of the input and output stages is also necessary.

Methods of suppressing parasitic oscillations are discussed in Question 92.

Q. 137. List several frequently used methods of attenuating harmonics in transmitters and explain how each works. 13.

A. Low Power Multiplier Stages. If frequency multipliers are used prior to the final amplifier, their power levels should be kept low. This will reduce the amount of spurious harmonic energy delivered to the final amplifier.

Effective By-Pass Capacitors. By-pass capacitors must be efficient at high frequencies. In other words, they must have low lead inductances so as not to form parallel tuned L-C circuits at a harmonic frequency.

Grid Bias. Final amplifier grid bias should be held low (consistent with other operating requirements).

Faraday Shields. Harmonic transfer through tuned transformers can be reduced by utilizing Faraday shields in the transformers.

Low Pass Filters. Low pass filters between the final stage and the antenna will attenuate frequencies above a certain point including the harmonics.

For additional discussion of harmonic attenuation, refer to Question 134.

14.

Q. 138. What is the meaning of the term "carrier frequency"?

A. The carrier frequency is the RF output frequency of a transmitter when there is no modulation.

Q. 139. If a carrier is amplitude modulated, what causes the sideband frequencies? 14.

A. The sideband frequencies are caused by the modulating signal. If a 10 Mc. (10,000 Kc.) carrier were to be modulated by a 1 Kc. modulating signal, the mixing would produce two new frequencies. They are called sidebands and they are the sum and difference of the two original frequencies.

However, if a broadcast carrier were modulated by speech, a number of sidebands above and below the carrier would appear. This is because speech contains many frequencies and each one mixes with the carrier to produce new frequencies.

Q. 140. What determines the bandwidth of emission for an AM transmission? 14.

A. The bandwidth of emission is determined by the highest modulating frequency applied to the carrier and is equal to twice this frequency. For example, if a 1,000 Kc. carrier is modulated by an audio signal which contains frequencies up to 5 Kc., but not higher, then the bandwidth would be 10 Kc. The signal would have as its

lower limit 995 Kc. and as its upper limit 1005 Kc.

Q. 141. Why does exceeding 100% modulation in an AM transmission cause excessive bandwidth of emission? 14.

A. When an AM transmitter is modulated in excess of 100%, new frequencies are generated which do not occur in the original modulating signal. These new frequencies occur over a wide range so that the sidebands develop on the carrier over a wide frequency spectrum causing excessive bandwidth.

Q. 142. What is the relationship between percent modulation and the shape of the waveform "envelope" relative to carrier amplitude? 14.

A. The relationship between percent modulation and the magnitudes of a symmetrically modulated wave are given by the following relationship:

$$\% \text{ Modulation} = \frac{\text{Emax} - \text{Emin}}{2\,\text{Eo}} \times 100$$

Where: Emax is the peak amplitude of the modulation envelope
Emin is the minimum amplitude of the modulation envelope
Eo is the magnitude of the wave with no modulation applied.

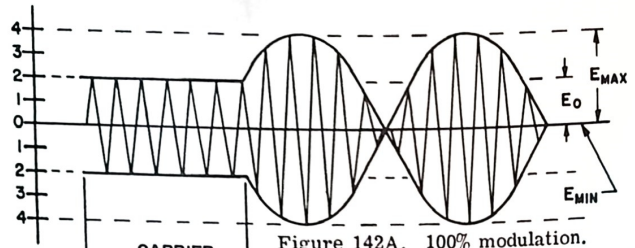


Figure 142A. 100% modulation.

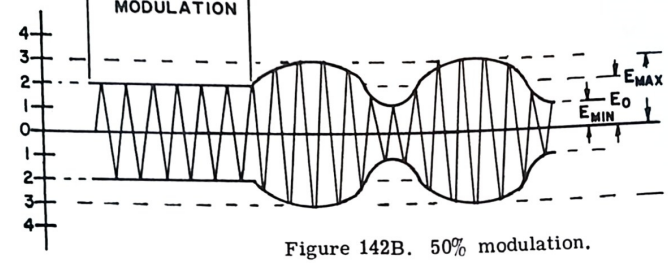


Figure 142B. 50% modulation.

Figure 142A shows a carrier modulated 100% by an audio sine wave. Note that Emin drops to 0 and Emax goes up to twice the unmodulated carrier amplitude.

Figure 142B shows a carrier modulated 50% by an audio sine wave. In this case, Emin drops to one-half of the unmodulated carrier amplitude and Emax goes up to one and one-half of the unmodulated carrier amplitude.

Q. 143. Draw a simplified circuit diagram of the final stages (modulator, modulated amplifier, etc.) of a type of low-level plate modulated transmitter, utilizing a pentode tube in the modulated stage. Explain the principles of operation. Repeat using a tetrode to provide high-level modulation. 14.

A. (a) Figure 143A illustrates low level modulation. Low level modulation means that a stage preceding the final RF amplifier is being modulated. In Figure 143A, V4 and V5 are the tubes in the modulator stage. The modulator amplifies the audio signal and by means of transformer, T1, feeds the audio to the plate circuit of V1, where it is superimposed on the RF carrier. Since the audio is fed into the plate circuit, we refer to this type of modulation as plate modulation.

The modulated RF signal is fed to the final RF amplifier stage (V2 and V3). Two tubes in push-pull are used for greater output power. The stage is operated as a Class B linear amplifier. This stage must be linear because the signal entering the stage contains audio which cannot be distorted. This stage could not be operated Class C since a Class C amplifier introduces considerable distortion.

(b) In Figure 143B, the carrier is modulated in the final RF amplifier stage. We refer to this as high level modulation. The final RF amplifier stage can be operated Class C since the audio is introduced in the plate circuit and we need not be concerned about the distortion that would occur had the signal been introduced in a previous stage.

Q. 144. How does a linear power amplifier differ from other types? 14.

A. A linear power amplifier differs from other power amplifiers in that the output voltage of the amplifier is an exact reproduction of the input voltage. It can therefore be used to amplify modulated signals such as single sideband signals and other "low-level" modulated signals. Most RF amplifiers are Class C and they amplify RF signals that do not contain any intelligence. A Class C amplifier introduces distortion. However, since there is no intelligence, we are not concerned. A linear power amplifier is Class B which has far less distortion than Class C.

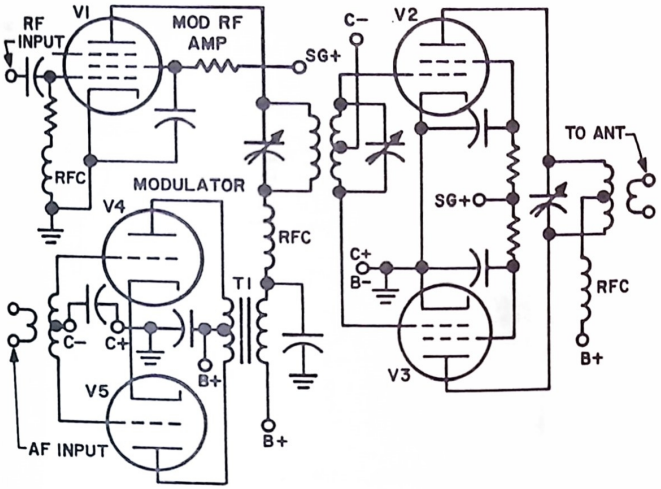


Figure 143A. Low-level modulation.

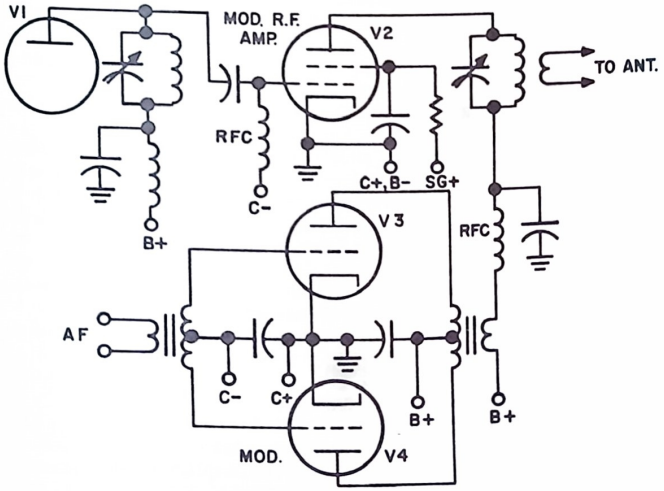


Figure 143B. High-level modulation.

Q. 145. Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio frequency power amplifier tube to produce grid modulation of the amplified RF energy. Compare some advantages or disadvantages of this system of modulation with those of plate modulation. 14.

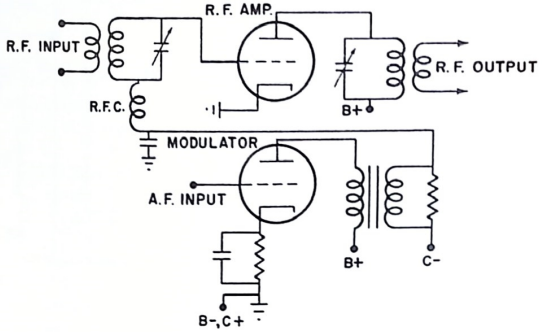


Figure 145. Grid modulation.

The principle advantage of grid modulation over plate modulation is that very little audio power is required. On the other hand, the output RF power of a plate modulated system is three to four times that of a grid modulated system. The critical adjustment and the non-linearity (with its subsequent distortion) are other disadvantages of a grid modulated transmitter compared to a plate modulated one.

Q. 146. What is meant by "frequency shift" or "dynamic instability" with reference to a modulated RF emission? 14.

A. The terms "frequency shift" and "dynamic instability", when used in reference to amplitude modulated radio-frequency emission, refer to changes of oscillator frequency as a result of changes in the plate and grid voltages of the oscillator tube. This is undesirable and is caused by poor voltage regulation of the power supply.

Q. 147. What would cause a dip in the antenna current when AM is applied? What are the causes of carrier shift? 14.

A. A dip in the antenna current in a plate modulated RF amplifier can be caused by the following:

(a) Grid bias is too low.
(b) RF excitation is inadequate.
(c) The tank circuit is overloaded.
(d) The load impedance is incorrect.
(e) The plate power supply for the amplifier has inadequate regulation.

A dip in the antenna current in a grid-bias modulated RF ampli-

fier can be caused by the following:

(a) Excessive RF excitation.
(b) Grid bias is too low.
(c) Grid resistance in grid bias supply is too high.
(d) Plate tank is inadequately loaded.
(e) Modulator and/or speech amplifier is generating excessive distortion.

Negative carrier shift can be caused by the following defects:

(a) Improper modulator bias.
(b) Modulator is overdriven.
(c) Modulator power supply had inadequate regulation.
(d) Overmodulation.
(e) Impedance mismatch between the modulator and the RF amplifier.

Positive carrier shift can be caused by the following defects:

(a) Inadequate neutralization.
(b) Improper RF amplifier tuning.
(c) Parasitic oscillations.
(d) Excessive audio drive.
(e) Inadequate RF excitation to the modulated amplifier.

Q. 148. What is the relationship between the average power output of the modulator and the plate circuit input of the modulated amplifier under 100% sinusoidal plate modulation? How does this differ when normal voice modulation is employed? 14.

A. For 100% sine wave modulation, the modulator must deliver power equal to 50% of the power input to the modulated RF amplifier. For 100% speech modulation only, the speech peaks should modulate the carrier at 100%. The average audio modulation power will be about one-half the sine wave value or about 25% of the power input to the RF amplifier.

Q. 149. What is the relationship between the amount of power in the sidebands and the intelligibility of the signal at the receiver? 14

A. Intelligibility will be highest when the carrier is modulated 100%. If the modulation percentage is lower, the audio signal at the output of the detector will be lower. At 100% modulation, the audio adds 50% additional power to the carrier. This additional power becomes the sideband power. Half of it goes into the upper sidebands and half goes into the lower sidebands.

Q. 150. What might cause FM in an AM radiotelephone transmitter? 14.

A. FM in an AM radiotelephone transmitter occurs if the frequency of the transmitter varies as the modulating signal varies. The most common cause would be a transmitter in which the DC power supply is common to both the modulator and the oscillator. Since the modulator has changing current requirements, the output voltage of the common DC power supply will vary. This changing

voltage would, in turn, vary the frequency of the oscillator.

Undesirable FM can be prevented by operating the modulator and the oscillator from separate DC power supplies.

Q. 151. Draw a block diagram of an AM transmitter. 14.

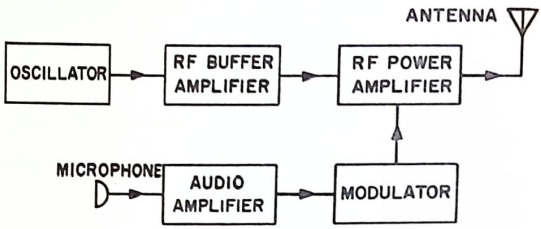


Figure 151. Block diagram of an AM transmitter.

Q. 152. Explain the principles involved in a single-sideband suppressed-carrier (SSSC) emission. How does its bandwidth of emission and required power compare with that of full carrier and sidebands? 14.

A. The principle of single-sideband suppressed carrier (SSSC) emission is to transmit only one of the sidebands. In other words, the carrier and one of the sidebands are eliminated from a conventional AM signal.

Only one sideband is necessary for conveying information. However, in a conventional AM transmitter, only 1/6th of the total DC power of the transmitter is in one sideband. Hence 5/6th of the power delivered to the transmitter's antenna is unnecessary for communication. Therefore, SSSC emission utilizes the minimum DC power necessary for communication. The SSSC signal requires a band only one-half the width of an AM signal since one of the sidebands is not transmitted.

Q. 153. Draw a block diagram of a SSSC transmitter (filter type) with a 20 Kc. oscillator and emission frequencies in the range of 6 Mc. Explain the function of each stage. 14.

A. A filter type of Single-Sideband Suppressed Carrier (SSSC) transmitter is shown in Figure 153 in block form. The frequency components at the output of each circuit are indicated to the right of each block by a sketch.

The 20 Kc. oscillator generates a single frequency reference signal. This signal combines with the audio output from the audio amplifier in the balanced modulator. The balanced modulator generates a double-sideband suppressed carrier with a center frequency

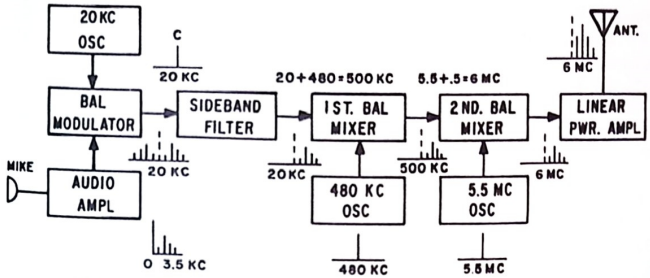


Figure 153. Block diagram of a single-sideband, suppressed carrier transmitter.

of 20 Kc. This means that the audio signal is distributed symmetrically above and below 20 Kc. However, the 20 Kc. signal is suppressed.

The double-sideband signal enters the sideband filter and emerges as a single-sideband (SSB) signal. The sideband filter has removed the lower sideband.

The 20 Kc. SSB signal is applied to a cascade of two balanced mixers. The first balanced mixer heterodynes the 20 Kc. SSB signal to 500 Kc. The 480 Kc. oscillator provides the signal required to perform the heterodyning process. The second balanced mixer and 5.5 Mc. oscillator repeat the heterodyning process raising the signal frequency to the required 6 Mc. The reason two mixers are employed is to ensure adequate image rejection of the 20 Kc. signal frequency.

The linear power amplifier (usually Class B) amplifies the 6 Mc. SSB signal to the power level required. The linear amplifier is necessary to preserve the audio which is already impressed on the carrier.

Q. 154. Explain, briefly, how a SSSC emission is detected. 15.

A. A receiver designed for the reception of single sideband suppressed carrier signals employs a heterodyne detector. Basically a heterodyne detector is a normal diode (AM) detector used in conjunction with a very stable beat frequency oscillator. The receiver is tuned in such a manner as to make the BFO signal take the place of the missing carrier. Normal AM detection may then take place.

Q. 155. Draw a block diagram of a single-conversion superheterodyne AM receiver. Assume an incident signal and explain briefly what occurs in each stage. 15.

A. See Figure 155. Let us assume that we wish to listen to a modulated signal at 2450 Kc. The RF amplifier stage is tuned to 2450 Kc. and amplifies the incoming signal. The local oscillator generates a signal whose frequency is 2906 Kc. The incoming signal

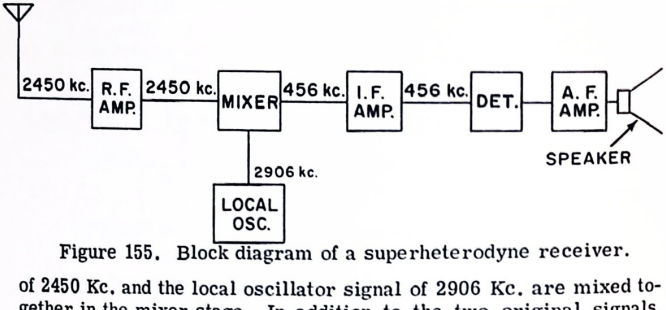


Figure 155. Block diagram of a superheterodyne receiver.

of 2450 Kc. and the local oscillator signal of 2906 Kc. are mixed together in the mixer stage. In addition to the two original signals, the mixer stage produces two new frequencies, namely, the sum and difference of the original frequencies. The mixing process does not destroy the audio of the incoming signal.

The intermediate frequency (IF) stage that follows the mixer is tuned to, and amplifies the difference in frequency, namely 456 Kc. The modulated IF signal then passes to the detector stage. The detector stage extracts the audio or intelligence from the modulated carrier and passes it on to the audio amplifier. Here, the audio is amplified and fed to the speaker.

Q. 156. Explain the relation between the signal frequency, the oscillator frequency and the image frequency in a superheterodyne receiver. 15.

A. Answer 155 explains the relation between the signal frequency and the oscillator frequency. The image frequency is the local oscillator frequency plus the Intermediate Frequency. In the diagram shown in Answer 155, the image frequency is 3362 Kc. If the local oscillator frequency was 456 Kc. below the incoming signal frequency, the image frequency would be 1994 Kc. The image frequency is the unwanted signal that beats with the local oscillator to produce the IF frequency.

Q. 157. Draw a circuit diagram of an AM second detector and AF amplifier (in one envelope), showing AVC circuitry. Also show coupling to, and identification of, all adjacent stages. 15.

(a) Explain the principles of operation.

(b) State some conditions under which readings of AVC voltage would be helpful in trouble-shooting a receiver.

(c) Show how this circuit would be modified to give DAVC.

A. (a) A circuit employing a vacuum tube as a second detector and audio amplifier is shown in Figure 157A. The cathode and plate, P1, form the diode detector. The same cathode together with the grid and plate, P2, serve as the first audio amplifier.

The IF signal from the IF amplifier is coupled through the IF transformer to the diode plate, P1 of tube V2. This diode demodulates the carrier so that the varying voltage which appears across volume control R2 is the audio signal which was originally impressed on the carrier. Capacitors C1 and C2, in conjunction with resistor R1, serve as an RF filter preventing the RF signal from entering the audio circuits. The audio signal which develops across the volume control is applied through coupling capacitor C3 to the triode section of V2. The amplified signal which appears at the plate is applied through capacitor C4 to the power amplifier stage.

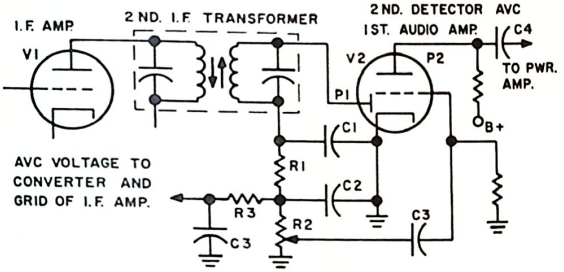


Figure 157A. An AM second detector and audio amplifier.

The negative AVC voltage develops across resistor R2. This voltage is due to the rectifier action of the second detector diode discussed in the previous paragraph. The AVC voltage is filtered by R3 and C3 which prevent audio from reaching the AVC circuits. The voltage is then applied to the grids of two or more of the tubes preceding the detector (IF, RF or mixer stages). The strength of the AVC voltage varies with the strength of the carrier. When the carrier decreases in strength, the negative AVC voltage becomes smaller and thereby reduces the grid voltage on the IF and RF tubes. When the carrier strength increases, the negative AVC voltage becomes larger and increases the grid voltage on these tubes. The tubes that receive the AVC voltage are called Variable-MU tubes and they are so constructed that their gain increases with a smaller negative grid voltage and decreases with a larger negative grid voltage. The volume is thereby maintained at a steady level despite changes in signal strength.

(b) Because the AVC voltage varies with the strength of the

signal reaching the second detector, it is a useful voltage to measure in both troubleshooting and aligning the receiver.

In the event that a receiver is inoperative, a voltmeter can be connected across R2 to measure the AVC voltage. If, when the receiver is tuned, the voltage rises and falls, signals are reaching the second detector and the fault probably is in the audio circuits.

On the other hand, if no AVC voltage variation occurs when the receiver is tuned, a signal at the IF frequency can be injected at the second IF transformer. The signal will cause AVC voltage to develop if the detector stage is working properly. The signal can then be moved, stage-by-stage, back to the antenna until the lack of AVC voltage indicates the defective circuit.

Finally, the AVC voltage is useful during alignment because it indicates when the RF circuits and the IF transformers are tuned for maximum signal strength (See Question 159).

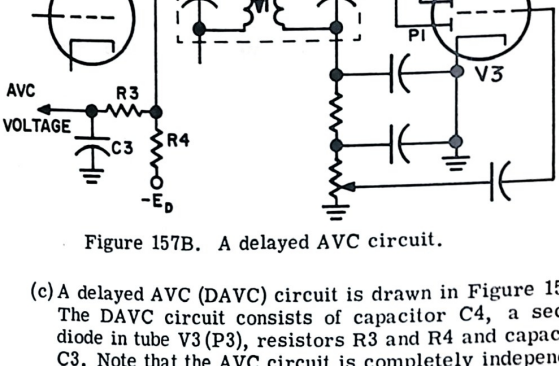


Figure 157B. A delayed AVC circuit.

(c) A delayed AVC (DAVC) circuit is drawn in Figure 157B. The DAVC circuit consists of capacitor C4, a second diode in tube V3 (P3), resistors R3 and R4 and capacitor C3. Note that the AVC circuit is completely independent of the second detector circuit.

Delayed AVC means that until the incoming signal reaches a certain minimum level, no AVC voltage develops and the RF and IF circuits are operating at maximum gain. This means that the receiver will have its maximum capability of receiving weak signals.

A small DC bias voltage is applied through resistor R4 to the AVC diode. As long as the carrier strength which

is applied to the AVC diode by capacitor C4 is less than the bias voltage, the diode does not conduct and no AVC voltage is developed. However, stronger signals will cause the diode to conduct and AVC voltage will be developed.

Q. 158. Draw a BFO circuit diagram and explain its use in detection. 15.

A. Any sine wave oscillator may be used as a beat frequency oscillator (BFO) for heterodyne detection. Heterodyne detection is required for the reception of code (CW) or suppressed carrier phone signals. Any of the usual AM detectors becomes a heterodyne detector when a BFO is used in conjunction with it. The amplitude of the BFO signal should be considerably larger than the strongest code or suppressed carrier signal if distortion is to be minimized.

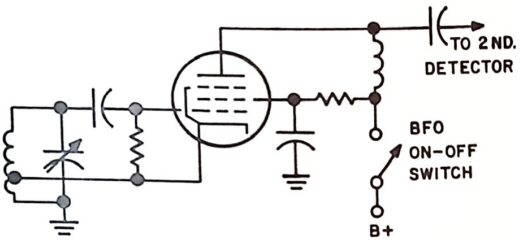


Figure 158. Circuit of a beat-frequency oscillator.

For the reception of suppressed carrier signals, the BFO operates to reintroduce the suppressed carrier at the receiver. The sideband signals beat with the BFO signal in the detector and normal audio results.

When receiving code signals, the BFO is adjusted to a frequency approximately 400 to 800 cycles different than the code signal. An audio note equal to this frequency difference will be produced at the detector output only when the code signal is present.

Q. 159. Explain, step-by-step, how to align an AM receiver, using the following instruments. Also explain briefly what is occurring during each step. 15.

(a) Signal generator and speaker.
(b) Signal generator and oscilloscope.
(c) Signal generator and VTVM.

A. The block diagram of a common superheterodyne broadcast receiver, including test equipment connections, is shown in Fig. 159.

The speaker, the oscilloscope or the VTVM can serve as tuning indicators. The speaker can be used to indicate when the circuits are tuned for maximum response. However, small changes in signal

level are difficult for the ear to detect. Therefore, an oscilloscope connected at the speaker will be a more satisfactory tuning indicator. When either the oscilloscope or the speaker is used as a tuning indicator, the signal generator must be modulated so that an audio signal will be available.

Should a VTVM be used, it can be connected to the AVC line. The AVC voltage will increase as the tuned circuits are adjusted for maximum output.

The alignment begins by injecting a signal at the IF frequency (usually 455 Kc.) at the input to the IF amplifier stage. The tuning slugs of the second IF transformer are adjusted for maximum output. The output of the signal generator is adjusted in this step (and each following step) for the lowest output possible. The procedure is repeated at the input to the converter tube. Due to interaction between the various stages, it is well to repeat the above procedure.

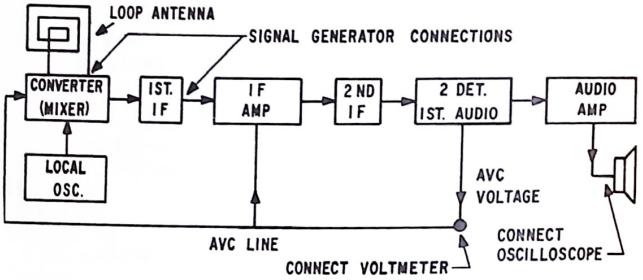


Figure 159. Aligning an AM superheterodyne receiver.

The signal generator is next set to 1400 Kc. and the dial of the receiver is also set to this frequency. The oscillator padder capacitor is adjusted so that the signal is tuned in. The signal generator is next coupled by means of a turn of wire to the loop antenna. The RF signal generator is set to 1400 Kc. and the RF trimmer capacitor is adjusted for maximum output.

Often, receivers have adjustable inductances as well as trimmer capacitors. By adjustment of both, it is possible to adjust the receiver so that the tuned circuits "track". Tracking means that as the receiver dial is tuned, the RF and oscillator circuits remain 455 kilocycles apart (the IF frequency) so that maximum performance is always obtained.

Q. 160. What would be the advantages and disadvantages of utilizing a bandpass switch on a receiver? 15.

A. The bandwidth occupied by a transmitted signal depends upon the type of modulation being used and the intelligence being transmitted. Double sideband phone signals require a receiver with an overall bandpass of, at least, 6 to 8 kilocycles for proper reception.

For the reception of single sideband signals, a bandpass of 2 to 3 kilocycles is necessary, while code signals require a bandpass of only 200 to 500 cycles.

(a) Advantages of utilizing a bandpass switch on a receiver. A bandpass switch may be used to adjust the overall bandpass of the receiver to accept the type of signal being received. A receiver with an overall bandpass equal to the bandwidth of the signal being received will operate with the best possible signal to noise ratio and will limit adjacent channel interference to a minimum.

(b) Disadvantages of utilizing a bandpass switch on a receiver. If the overall bandpass of the receiver is less than the bandwidth of the signal being received, the detected signal will be a distorted version of the original modulating signal. The tuning of a receiver with a narrow overall bandpass becomes more critical. In addition, local oscillator frequency stability becomes increasingly important as the bandpass narrows. On the other hand, if the overall bandpass of the receiver is greater than the bandwidth of the signal being received, the signal to noise ratio becomes poorer and adjacent channel interference will increase.

Q. 161. Explain: Sensitivity of a receiver; selectivity of a receiver. Why are these important quantities? In what typical units are they usually expressed? 15.

A. (a) The sensitivity of a receiver is commonly described in the following three ways:

(1) Sensitivity can be specified in terms of the signal required at the input to achieve a certain output power at the speaker. For example, a standard specification for a broadcast receiver is to specify the input voltage (in microvolts) modulated at 30% at 400 cycles to develop 1/2 watt at the speaker. This specification describes the overall gain of the receiver.

(2) A second specification states the input to achieve a ratio of signal plus noise to the noise output of the receiver. This is called the "signal-to-noise ratio". It is usually expressed in decibels. For example, a receiver might require 1/2 microvolt input to achieve a 10 decibel signal-to-noise ratio. The signal-to-noise ratio is a more useful definition than the first definition for a communication receiver because it takes into account noise which is a crucial factor in weak signal reception.

(3) Above 30 Mc., the atmospheric and man-made noise entering the receiver decrease and the factor affecting receiver sensitivity is the noise generated within the receiver. This sensitivity is specified by "noise figure". This is the ratio of the signal-to-noise ratio of an ideal receiver to the signal-to-noise ratio of the actual receiver. Noise figure is usually expressed in decibels. The best noise figure would be zero decibels. Receivers in the VHF region usu-

ally have noise figures between 2 and 7 decibels.
(b) When a receiver is tuned to a signal at a certain frequency, it is desirable that signals slightly above and below in frequency be rejected. The ability of the receiver to respond to only the single signal is a measure of its selectivity. Selectivity is specified by "bandwidth". Bandwidth is the frequency range over which the received signal is above a certain level. For example, a "bandwidth of 4 Kc. at the 6 decibel points" means that over a frequency range of 4 kilocycles, signals received will not be attenuated by any more than 6 decibels. This response curve is drawn in Figure 161 for a receiver tuned to 10 megacycles.

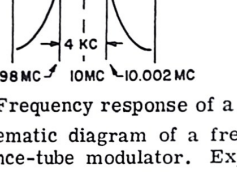


Figure 161. Frequency response of a receiver.

Q. 162. Draw a schematic diagram of a frequency-modulated oscillator using a reactance-tube modulator. Explain its principle of operation. 16.

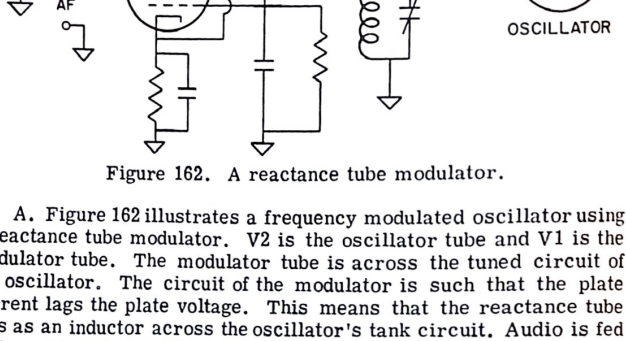


Figure 162. A reactance tube modulator.

A. Figure 162 illustrates a frequency modulated oscillator using a reactance tube modulator. V2 is the oscillator tube and V1 is the modulator tube. The modulator tube is across the tuned circuit of the oscillator. The circuit of the modulator is such that the plate current lags the plate voltage. This means that the reactance tube acts as an inductor across the oscillator's tank circuit. Audio is fed to the grid of the modulator tube and causes its plate current to vary accordingly. These audio variations cause the "acting" inductance to vary and this, in turn, causes the oscillator's frequency to vary.

Thus, frequency modulation is produced. In Figure 162, the reactance tube acts as an inductance. In some circuits, the reactance tube can act as a capacitance.

Q. 163. Discuss the following in reference to frequency modulation: 16.

(a) The production of sidebands.
(b) The relationship between the number of sidebands and the modulating frequency.
(C) The relationship between the number of sidebands and the amplitude of the modulating voltage.
(d) The relationship between percent modulation and the number of sidebands.
(e) The relationship between modulation index or deviation ratio and the number of sidebands.
(f) The relationship between the spacing of the sidebands and the modulating frequency.
(g) The relationship between the number of sidebands and the bandwidth of emissions.
(h) The criteria for determining bandwidth of emission.
(i) Reasons for pre-emphasis.

A. (a) When the modulation applied to an FM transmitter is a single frequency, a large number of side frequencies (called sidebands) are generated and are spaced symmetrically on both sides of the carrier frequency. The sidebands are spaced apart by an amount equal to the modulation frequency. The production of sidebands for FM therefore differs from AM modulation in which the single modulating frequency produces only two sidebands. See Figure 163.

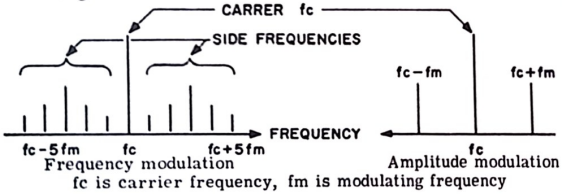


Figure 163. A carrier modulated by a single frequency.

(b) If the frequency deviation remains the same, the number of sidebands will vary inversely with the modulation frequency. For example, if the modulating frequency is increased, the number of sidebands will decrease.
(c) As the modulating voltage is increased, the number of sidebands will increase in direct proportion and vice versa.
(d) "Percent modulation" in FM broadcasting is determined by the frequency deviation of the carrier which occurs

when the modulation is impressed. A deviation of plus or minus 75 Kc. is 100% modulation. The number of sidebands increases proportionally with an increasing percentage of modulation.

(e) The "modulation index" is determined by the following relationship:

$$\text{Modulation index} = \frac{\text{Carrier frequency deviation}}{\text{modulating frequency}}$$

The number of sidebands increases as the modulating index increases.

The "deviation ratio" is the modulation index corresponding to the maximum carrier frequency deviation and the highest modulating frequency. It, too, is proportional to the number of sidebands.

(f) The sidebands are spaced apart by the frequency of the modulating signal. For example, if a 4 Mc. signal is frequency modulated by a 1 Kc. signal, then sidebands will occur at 4001 Kc. (4.001 Mc.), 4002 Kc. and so on. The sidebands will also occur at 3999 Kc., 3998 Kc., etc.

(g) As explained in (f) above, the sidebands are spaced apart by the frequency of the modulating signal. These sidebands occur both above and below the carrier frequency. Hence the greater the number of sidebands, the wider the bandwidth of the emissions.

(h) The bandwidth of emission is determined by the maximum deviation. High fidelity FM broadcasting employs a peak deviation of 75 Kc. Because this deviation swings both above and below the carrier frequency, the bandwidth of emission is twice 75 Kc. or 150 Kc.

(i) Pre-emphasis is utilized to insure that the high frequency portions of the transmitted FM signal are properly reproduced by the receiver. The high frequency signals must compete with noise at the receiver because noise is in the high frequency region. Consequently, to insure that the high frequencies will be stronger than the noise, these frequencies are pre-emphasized. This means they are transmitted at higher amplitudes than the lower frequencies. A de-emphasis circuit in the receiver restores the original signal so that the amplitudes of the respective low and high frequencies are faithfully reproduced at the output of the receiver.

Q. 164. How is good stability of a reactance tube modulator achieved? 16.

A. Good stability of a reactance tube modulator can be achieved by using the following methods:

(1) The master oscillator should be operated at a low-frequency to maintain high carrier stability. Frequency multipliers

can be used to bring the carrier up to its correct transmitted frequency.

(2) Use a regulated power supply for both the modulator and oscillator.

(3) Use a high capacity in the tank circuit of the oscillator (taking into account other operating factors which may not allow for too high a capacity).

(4) Use an automatic frequency control system which keeps the center carrier frequency fixed. We do this by feeding back correcting voltages to the reactance tube to counteract any tendency on the part of the oscillator or reactance tube stages to alter the transmitter frequency.

Q. 165. Draw a circuit diagram of a phase modulator. Explain its operation. Label adjacent stages. 16.

A. Figure 165 illustrates a simplified schematic of a phase modulator. The audio is fed to the grid of the tube through transformer T1. As the amplitude of the audio signal varies, the transconductance of the tube varies. The RF from a crystal-controlled oscillator is also fed to the grid of the modulator. Part of this RF goes directly to the plate circuit through the grid-to-plate capacitance of the tube. This is referred to in the diagram as E_{GP}. The other part appears at the grid circuit to be amplified by the tube. This later RF appears at the plate after amplification (E_{AMP} in Figure 165); however, its phase is changed in the amplification process. Thus, we have two out of phase RF signals at the plate circuit. These two signals add together (by vector addition) to give a resultant signal (E_R) which is then fed on to the frequency multiplier stages.

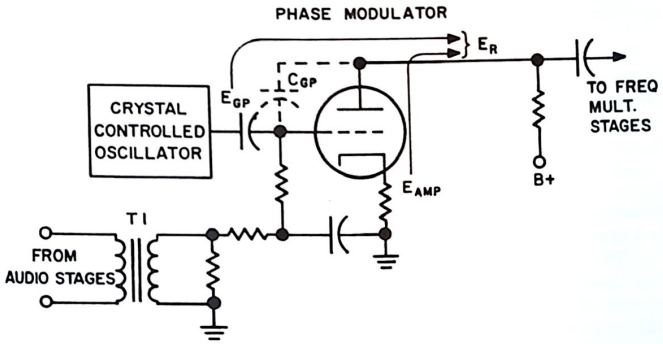


Figure 165. A phase modulator.

As the audio varies, the transconductance varies accordingly. The varying transconductance causes the magnitude of E_{AMP} to vary.

When this happens, the resultant voltage, E_R will vary in phase - the greater the voltage variation of E_{AMP}, the greater will be the phase variation of E_R. Thus we see how an audio signal is superimposed on a carrier in the form of phase variations.

Q. 166. Explain, briefly, what occurs in a waveform if it is phase modulated. 16.

A. Phase modulation is produced when the phase of a carrier is shifted from its resting frequency. As the phase of the carrier is shifted, its frequency is being instantaneously changed automatically. This can be seen from Figure 166.

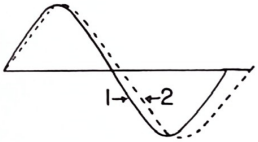


Figure 166. A phase modulated wave.

Let us assume that wave No. 1 is the sinewave of a carrier with no modulation applied. It has a specific fixed frequency. Wave No. 2 is the same sinewave, as it would have appeared if phase modulation had been applied. The phase of wave No. 2 is altered by phase modulation and it lags behind No. 1. But in order to lag, it must slow down instantaneously. This "slow down" is actually a reduction or change in frequency. If wave No. 2 were to lead wave No. 1, there would be an instantaneous increase in frequency. Thus we see how a change in the phase of a carrier results in frequency changes or deviation.

Q. 167. Explain, in a general way, why an FM deviation meter (modulation meter) would show an indication if coupled to the output of a transmitter which is phase-modulated by a constant amplitude, constant audio frequency. To what would this deviation be proportional? 16.

A. The FM deviation meter will show an indication because phase modulation does cause an instantaneous frequency change or deviation at the moment that the phase is shifted. This is discussed in Answer 166 above.

The amount of deviation in a phase modulated system depends upon how rapidly the phase shift is taking place and upon the total amount of the phase shift. Thus we see that the final frequency deviation in a phase modulated system depends upon the frequency and the amplitude of the modulating signal.

Q. 168. Draw a circuit diagram of each of the following stages of a phase-modulated FM transmitter. Explain their operation. Label adjacent stages.

(a) Frequency multiplier (doubler) with capacitive coupling on input and output. 13.

(b) Power amplifier with variable link coupling to antenna. Include circuit for metering grid and plate currents.16.

(c) Speech amplifier with an associated pre-emphasis circuit.16

A. (a) Figure 168A illustrates a frequency doubler stage. It is operated Class C with a very high value of bias. The plate tank circuit is tuned to twice the frequency that is present in the grid circuit. The Class C amplifier introduces considerable harmonic distortion. Since the plate circuit is tuned to the second harmonic, the second harmonic (twice the input signal frequency) becomes the output frequency.

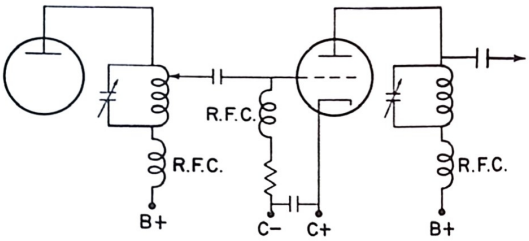


Figure 168A. A frequency doubler.

(b) Figure 168B illustrates an RF power amplifier coupled to an antenna. The RF signal fed to its grid comes from a preceding RF buffer amplifier stage. A triode tube amplifies the signal and it is link coupled to the antenna circuit. Meter M1 reads the current flowing in the grid circuit and M2 reads the plate current. Capacitor C_N

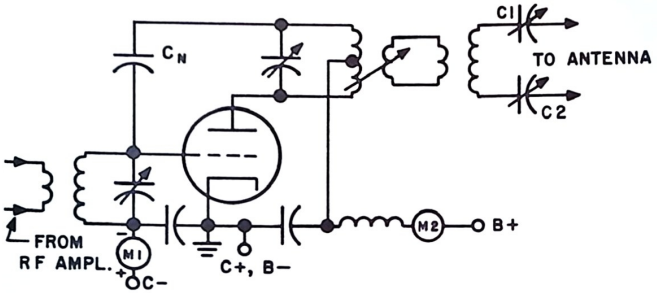


Figure 168B. A power amplifier with variable link coupling.

provides the neutralization required for a triode tube. The amount of energy transfer between the plate circuit and the antenna circuit can be controlled by adjusting the variable link. Proper impedance matching to the antenna can be obtained by adjusting Capacitors C1 and C2.

(c) Figure 168C illustrates an ordinary audio amplifier stage with a pre-emphasis network. The audio signal appearing at the transformer is an amplified version of the signal appearing at the output of the microphone. The purpose of the pre-emphasis network is to increase the relative strength of the high frequency audio components compared to the low frequency components. R and L constitutes the pre-emphasis network. The higher audio frequencies causes L to have a greater inductive reactance than the lower audio frequencies. The higher audio frequency components therefore create a larger voltage drop across L. This is impressed on the grid of the following stage. Thus we see that the output of the transmitter will contain audio whose high frequency components are greater than the low frequency components. The receiver contains a de-emphasis network which brings the high frequency audio components down to normal.

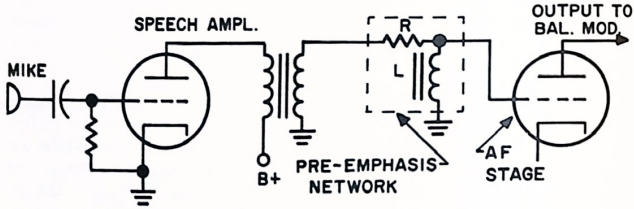


Figure 168C. Speech amplifier including a pre-emphasis circuit.

Q. 169. Discuss wide-band and narrow-band reception in FM voice communication systems with respect to frequency deviation and bandwidth. 16.

A. Wide-band and narrow-band reception in FM refers to the amount of frequency deviation with its consequent bandwidth that the FM signal occupies. For instance, the regular FM broadcast stations use a peak frequency deviation of 75 Kc. Since the deviation swings are on both sides of the center frequency, the total swing is 2 x 75 Kc. or 150 Kc. Thus the actual bandwidth occupied by the signal is 150 Kc.

In FM voice communications, it is not necessary to have a large frequency deviation. Also, the bands used for voice communications (such as police, fire, Air Force, etc.) are too crowded to occupy

wide bandwidths. Police and fire signals in the 150 Mc. - 170 Mc. region use a frequency deviation of only 5 Kc. for a total bandwidth of 10 Kc. We refer to this as narrow-band FM. Above 400 Mc., the various communications services use a frequency deviation of 15 Kc. for a total bandwidth of 30 Kc. This is referred to in voice communications as wide-band FM.

Q. 170. What might be the effect on the transmitted frequency if a tripler stage in an otherwise perfectly aligned FM transmitter, were slightly de-tuned? 16.

A. The primary purpose of a tripler stage is to provide an output signal frequency three times higher than the input signal frequency. Very slight detuning of the resonant circuit of a tripler stage would not change the transmitted frequency of an otherwise perfectly aligned FM transmitter. As the detuning becomes more severe, unwanted frequencies are injected into the signal. This shows up as interference at the receiving end.

Q. 171. Could the harmonic of an FM transmission contain intelligible modulation? 16.

A. The harmonics of an FM transmission contain intelligible modulation. The only difference between the intelligence of the harmonic and that of the actual carrier is an increased frequency deviation. The second harmonic will have a frequency deviation twice the frequency deviation of the fundamental or carrier.

Q. 172. Under what usual conditions of maintenance and/or repair should a transmitter be re-tuned? 16.

A. If tubes or transistors are replaced, or if resonant circuits, RF components and RF leads are replaced or repaired, the transmitter should be retuned. As a general rule, the higher the operating frequency of the transmitter, the more likely it will require retuning after repair. The repair of power supply and control circuits will normally not affect the operating frequency of a transmitter.

Q. 173. If an indirect FM transmitter without modulation was within carrier frequency tolerance, but with modulation was out of tolerance, what might be some of the possible causes? 16.

A. The possible causes of the unwanted frequency shift lie primarily in the modulation circuits. A common type of phase modulation uses a balanced modulator consisting of two tubes in a push-pull arrangement. If any of the modulator tubes should become weak, the output would be unbalanced, and if we modulate with an unbalanced signal, the average output frequency (carrier) will be shifted. The same would be true if any of the other parts in the modulator became defective.

Undesirable feedback between the modulator and the oscillator would also cause a frequency shift when the modulator was turned on.

Another cause of frequency drift might be poor power supply

regulation. Load changes due to the modulator could affect the oscillator's voltage which, in turn, could cause the oscillator's frequency to vary slightly.

Q. 174. In an FM transmitter what would be the effect on antenna current if the grid bias on the final power amplifier were varied? 16.

A. If the control grid bias of the final power amplifier was increased, the antenna current would decrease. A decrease in the control grid bias would have an opposite effect.

Q. 175. Explain, briefly, the principles involved in frequency-shift keying (FSK). How is this signal detected? 16.

A. Frequency-shift keying (FSK) is a means of keying a transmitter by varying its frequency. The amplitude of the carrier is kept constant and when the key is depressed, the output frequency is shifted or changed by approximately 1000 cycles. An FSK signal is detected by an FM detector (limiter and discriminator) which can be in either the IF amplifier, or in the audio amplifier, if a beat frequency oscillator is used.

Q. 176. Assume you have available the following instruments: AC-DC VTVM; AMMETER; HETERODYNE FREQUENCY METER (.0002% accuracy); ABSORPTION WAVE METER; FM MODULATION METER.

Draw and label a block diagram of a voice modulated (press-to-talk microphone), indirect (phase-modulated) FM transmitter having a crystal multiplication of 12.

(a) If the desired output frequency were 155.460 Mc., what would be the proper crystal frequency? 16.

(b) Consider the transmitter strip completely de-tuned; there are ammeter jacks in the control grid circuits of the multipliers and the control grid and cathode circuits of the final circuits of the final amplifier. Explain, in detail, step-by-step, a proper procedure for tuning and aligning all stages except plate circuit of final power amplifier (P.A.). 16.

(c) Assume a tunable antenna with adjustable coupling to the plate circuit of the final P.A. With the ammeter in the cathode circuit of the P.A. and with the aid of a tube manual, describe a step-by-step method of obtaining maximum output power, without damage to the tube. 16.

(d) If the P.A. in (c) above were a pentode, how would you determine the power input to the stage? 8.

(e) In (c) above, how would you determine if the P.A. stage were self-oscillating; if so, what adjustments could be made? 13.

(f) Assume the transmitter's assigned frequency is 155.460 Mc., with a required tolerance of ± .0005 percent. What

would be the minimum and maximum frequencies, as read on the frequency meter, which would assure the transmitter being within tolerance? 18.

(g) Assume the 1 Mc. crystal oscillator of the frequency meter has been calibrated with WWV and that the meter is tunable to any frequency between each 1 Mc. interval over a range of 20-40 Mc., with usable harmonics up to 640 Mc. Explain in detail what connections and adjustments would be made to measure the signal directly from the transmitter; also by means of a receiver. 18.

(h) If in checking the frequency deviation with the modulation meter, would you expect the greatest deviation by whistling or by speaking in a low voice into the microphone? 16

(i) If the transmitter contained a means for limiting, and were overmodulating, what measurements and adjustments could be made to determine and remedy the fault. 16

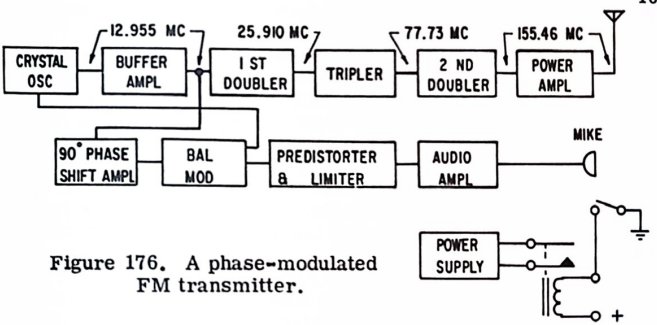


Figure 176. A phase-modulated FM transmitter.

A. A block diagram of a phase modulated transmitter is shown in Figure 176.

(a) Since the total multiplication is 12, the crystal frequency would be one-twelfth of 155.460 Mc. or 12.955 Mc.

(b) 1) Remove the plate and screen power from the final amplifier and leave it off until the final stage is aligned.

2) Insert the ammeter (we actually use a milliammeter) into the grid circuit of the buffer amplifier.

3) With the power on and the proper crystal in place, adjust the plate tank capacitor of the oscillator for maximum reading.

4) Loosely couple the wavemeter to the output of the oscillator to make certain that the output tank circuit is resonant to the correct frequency. The wavemeter gives an approximate indication, which is sufficient for this check.

5) Loosely couple the heterodyne frequency meter to the

output of the oscillator to determine that the crystal frequency is exact.

6) Place the milliammeter in the grid circuit of the 1st doubler and adjust the buffer tuned circuits for maximum reading.

7) Use the wavemeter to roughly check that the buffer tuned circuits are set to their correct frequency and not to an incorrect harmonic.

8) Place the milliammeter in the grid circuit of the tripler stage and adjust the 1st doubler tuned circuits for maximum reading. Use the wavemeter to check that the plate tank circuit of the 1st doubler is tuned to the correct harmonic frequency (approximately 26 Mc.).

9) Place the milliammeter in the grid circuit of the 2nd doubler stage and adjust the tuned circuits of the tripler stage for maximum reading. Use the wavemeter to make certain that the output frequency from the tripler stage is tuned to approximately 77-78 Mc.

10) Place the milliammeter in the grid circuit of the Power Amplifier stage and peak the tuned circuits in the 2nd doubler stage and the tuned circuit in the grid section of the Power Amplifier stage (if there is one) for maximum reading. Use the wavemeter to verify that the output frequency of the doubler is approximately 155-156 Mc.

(c) 1) Connect the output antenna circuit to a dummy load.

2) Adjust the antenna coupling to minimum and insert the milliammeter (or ammeter) into the cathode circuit of the P.A.

3) Turn the plate and screen voltages on and QUICKLY adjust the plate tank circuit for minimum cathode current.

4) Adjust the antenna tuned circuit for maximum cathode current. Check the tube manual for the proper plate current. Subtract the approximate screen and control grid currents from the cathode current to arrive at the plate current. If the plate current is not high enough, increase the antenna coupling slightly. Readjust the plate tank capacitor for a dip in the cathode current. Continue to adjust the antenna coupling and the plate capacitor until the plate current is in accordance with the tube manual.

5) Insert the milliammeter into the P.A. grid circuit and readjust slightly the P.A. grid tank capacitor and the output capacitor of the 2nd doubler stage for maximum grid current. Do not exceed the maximum grid current given in the tube manual.

6) Disconnect the power, remove the dummy load and connect the antenna.

7) Turn on the power and make the necessary slight adjustments since the dummy load may not present the exact same

load to the transmitter as the actual antenna will.

(d) First we must determine the plate current by subtracting the control grid current and screen grid current from the cathode current. The cathode and control grid currents can be measured and the approximate screen current can be determined from the tube manual. If the exact screen current is required, it can be measured by inserting the milliammeter into the screen circuit. Once we determine the plate current, we simply multiply it by the plate voltage to obtain the input power to the stage.

(e) Self-oscillation would be indicated if there were grid current flow with the RF excitation to the stage removed. Self-oscillation would also be indicated by erratic cathode current reading as the plate tank capacitor is slowly adjusted through resonance. If the stage is neutralized, the neutralizing adjustments should be made. If the stage is not neutralized, the chances are that the antenna tuned circuit needs adjustment.

(f) Since the Heterodyne Frequency Meter can have a .0002% error, the frequencies as read by this meter should be within ±.0003%. Converted to an actual frequency, it would be: 155.460 Mc. x .000003 = .00046638 Mc. Thus the minimum frequency would be 155.460 Mc. - .00046638 or 155.45953362 Mc. The maximum frequency would be 155.460 + .00046638 = 155.46046638 Mc.

(g) First we set up the signal generator part of the Heterodyne Frequency Meter so that it generates approximately 38.865 Mc. The 4th harmonic of this is approximately 155.460 Mc. We then tune in the transmitter's output which should be exactly 155.460 Mc. We can then listen for the zero beat of the transmitter's signal and the 4th harmonic of the signal generator in the output of the Heterodyne Frequency Meter. The dial on the frequency meter is then read for the exact frequency of the transmitter. A receiver can accomplish the same thing. It can pick up the transmitter's signal and compare it with the 4th harmonic of the signal generator part of the Heterodyne Frequency Meter.

(h) A phase modulated FM transmitter contains a pre-distorter circuit which insures the fact that the deviation of the FM signal will depend only upon the amplitude of the modulating signal and not upon the frequency of the modulating signal. Therefore, if the amplitude of the whistling is the same as the amplitude of the voice, the frequency deviation will be the same in the modulation meter.

(i) Overmodulation can be determined with a modulation meter which measures the amount of frequency deviation. If overmodulation is present, the limiting control can be adjusted to limit at a lower level.

Q. 177. Draw a schematic diagram of each of the following stages of a superheterodyne FM receiver. Explain the principles of operation. Label adjacent stages. 16.

(a) Mixer with injected oscillator frequency.
(b) IF amplifier.
(c) Limiter.
(d) Discriminator.
(e) Differential squelch circuit.

A. (a) Figure 177A illustrates a mixer stage with its associated oscillator stage. The incoming RF signal is applied to the mixer grid through T1. The local oscillator, which is an ordinary Hartley oscillator, generates a signal and injects it into the mixer stage through the coupling capacitor C_C. The oscillator frequency is a specific amount above or below the incoming signal frequency. The two signals "beat" together or "mix" together in the mixer stage and produce two new frequencies - the sum and difference of the two original frequencies. Transformer T2 is tuned to the difference frequency and therefore, picks this one out. This "difference frequency" is called the Intermediate Frequency (IF) and the stage following T2 is called the IF amplifier stage.

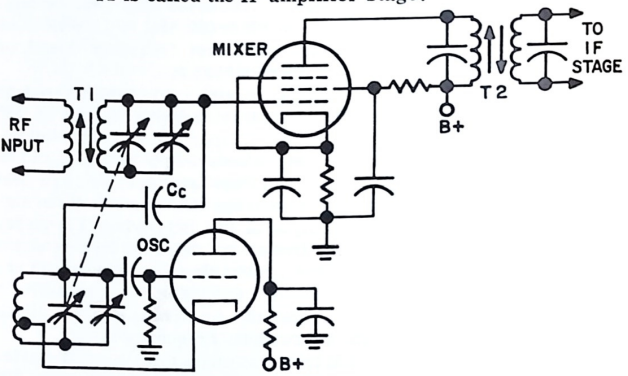


Figure 177A. A mixer with its local oscillator.

(b) An IF amplifier is shown in Figure 177B. The stage operates as a Class A amplifier using cathode bias. Since the IF transformers, T1 and T2 are tuned to the same frequency, a pentode must be used to avoid external neutralization. Resistors R1 and R2 are used to broaden out the response curve of the IF amplifier. We require a broad response curve because the FM signal occupies a wide bandwidth. In the case of an FM broadcast station, it is 150 Kc. wide.

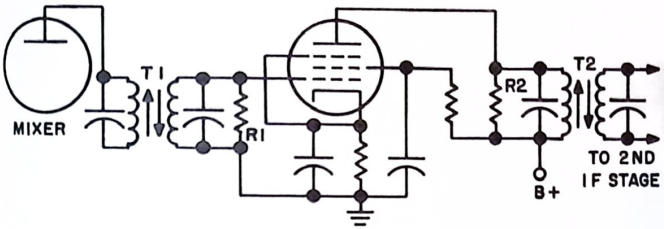


Figure 177B. IF amplifier stage.

(c) The purpose of the limiter stage is to clip or cut the amplitude variations in the FM signal. The amplitude variations represent interference or noise and are removed by the limiter stage before the signal gets into the FM detector. Figure 177C shows a typical limiter stage. In addition to using a sharp cutoff tube, grid-leak bias is used and the tube is operated with low plate and screen voltages. The grid-leak bias responds quickly to sudden amplitude variations and counteracts them. For instance, if the input signal suddenly increased, the bias would increase and reduce the gain of the stage.

The low plate and screen voltages cause the tube to reach saturation quickly and the tube will not respond to input voltages above a certain value. To insure proper limiting, the input signal to the limiter must be large enough to reach the saturation point. The gain of the limiter is low, since its primary function is to limit rather than amplify.

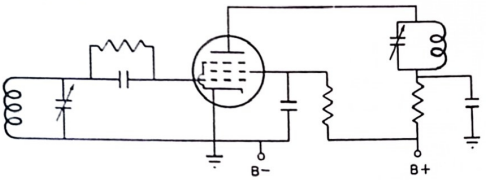


Figure 177C. A limiter stage.

(d) The discriminator of an FM receiver is similar in function to the detector of an AM receiver. It extracts the audio from the carrier. However, whereas the AM detector takes the audio from the peaks of the carrier, the FM detector converts the frequency changes into amplitude variations. These amplitude variations constitute the audio signal.

Figure 177D illustrates a common form of discriminator known as the Foster-Seeley discriminator or the Phase

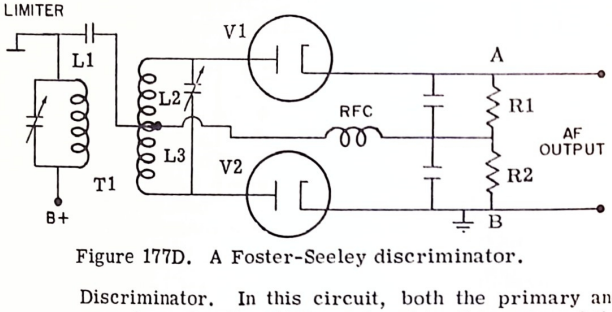


Figure 177D. A Foster-Seeley discriminator.

Discriminator. In this circuit, both the primary and secondary circuits of T1 are tuned to the center of the intermediate frequency. The voltages across L2 and L3 are equal to each other. With no modulation present, these two voltages are 90° out of phase with the voltage across L1. Under this condition, the current in V1 is equal to the current in V2 and the voltage drop across R1 will be equal and opposite to the voltage drop across R2. The output voltage across AB will, therefore, be zero. When modulation is present, the frequency varies and the phase angle between the voltage in the primary and secondary vary above and below 90°, depending upon which way the frequency is shifting. As the phase varies, the resultant voltages across V1 and V2 change. This will cause the voltages across R1 and R2 to vary, thereby producing a resultant voltage across AB. Thus we see how frequency variations are converted into amplitude (audio) variations.

(e) The purpose of the differential squelch is to silence the FM receiver when no signal is being received. With no signal being received, there is a hash or hiss noise that is offensive to most listeners. Figure 177E illustrates a simplified schematic of a differential squelch circuit. It operates as follows:

The output of the discriminator is fed to points A and C. The negative limiter bias is fed to point B. With no signal, the noise will appear at point A and be amplified by V1, the noise amplifier. The network, C1 and R1, favors the noise and rejects the signal. The amplified noise then goes to the noise diode where it is rectified. The rectified DC resulting from the noise appears as a positive voltage on the grid of the squelch gate tube V2. This causes heavy plate current to flow through V2 and R3. Since R3 is the cathode bias resistor for V3, the heavy current will cause a large bias voltage across R3, which will cut off V3. Since V3 is the first audio amplifier,

nothing will get through to the speaker. Thus we see how the receiver is squelched when no signal is received.

When a signal is received, the limiter operates to cut down the noise and the amount of noise appearing at V1 is almost zero. In addition to this, the incoming signal creates a strong negative limiter bias which appears at point B. This appears at the grid of V1 and cuts V1 off. Thus, the output of V1 is zero and consequently, the voltage appearing at the grid of V2 from the noise amplifier and diode is at a minimum. Under these conditions, the cathode bias at V2 is such that V2 is almost cut off. The large bias voltage at V3 disappears and V3 operates normally. Thus we see how the receiver operates normally when a signal is received.

The disadvantage of using a squelch circuit is that it will cut out those weak signals which are not stronger than the noise. To overcome this, a squelch control (R2) is used to control the squelch action to receive the weak signals. If a signal is very weak, a switch can be employed to cut out the squelch circuit entirely.

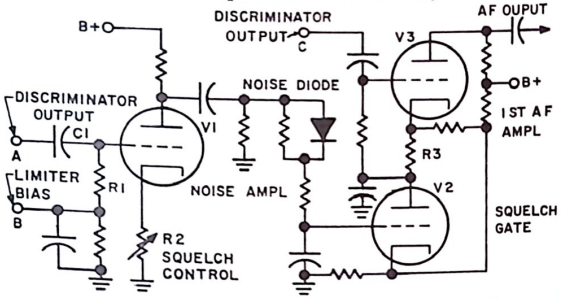


Figure 177E. A differential squelch circuit.

Q. 178. Draw a diagram of a ratio detector and explain its operation. 16.

A. A ratio detector is a detector that is used in an FM receiver. It is actually a combination of an FM discriminator (another form of FM detector) and a limiter. Hence, it does not require a separate limiter stage. FM receivers that use a limiter also require a greater number of IF stages to bring the FM signal up to a certain level to properly operate the limiter. Hence, an FM receiver, using a ratio detector is more economical to produce than one that uses the limiter-discriminator form of detector.

Figure 178 shows a type of ratio detector. When the incoming FM signal is at its center frequency, the voltage across L1 is equal to the voltage across L2. The voltages across C1 and C2 are, therefore, equal and they add up to the voltage across R1. As the incoming FM frequency varies from one side to the other, the output voltages at C1 and C2 will vary. The audio output voltage is taken across C2.

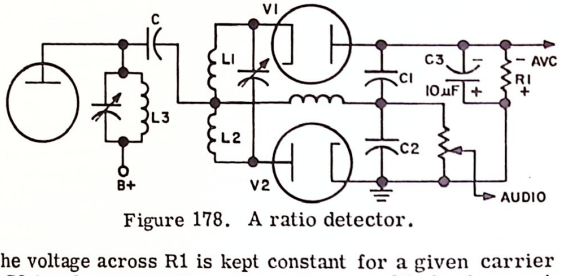


Figure 178. A ratio detector.

The voltage across R1 is kept constant for a given carrier because C3 is a large capacitor. Momentary amplitude changes in the carrier will have no effect on the voltage across R1. Since the voltage on R1 is equal to the sum of the voltages on C1 and C2, the amplitude variation of the incoming signal will have no effect on voltages across C1 and C2. They will vary only in accordance with the frequency variations at L1-L2. If the carrier strength changes (such as tuning in a stronger station), a new voltage will establish itself across R1 and will not change due to any instantaneous amplitude variations in the signal. Thus we see how limiting action can be accomplished in a ratio detector.

Q. 179. Explain how spurious signals can be received or created in a receiver. How could this be reduced in sets having sealed untunable filters? 15.

A. (a) The following types of spurious signals can be received or created in a receiver:

(1) Harmonics of the local oscillator may beat with an unwanted incoming signal to produce a signal of approximately the same frequency as the IF.

(2) Images. An image is a signal differing from the local oscillator frequency by an amount equal to the IF frequency. It is usually above the local oscillator frequency, whereas the desired signal is below the local oscillator frequency.

(3) Harmonics of the incoming signal generated by the mixer stage will be heard as spurious signals.

(4) A signal whose frequency is equal to the intermediate frequency of the receiver will generally manage to get through the mixer stage to be heard by the listener.

(5) Two RF signals whose difference is equal to the IF of the receiver will beat together to produce a spurious signal.

(6) If the receiver's overall selectivity is not too good, the signals from adjacent channels will be heard.

(b) A sealed untunable filter will improve the receiver's selectivity considerably. The filter is usually placed in the low frequency IF section. It is sharply tuned and will allow only the proper IF signal to pass. Adjacent channel signals and all other interfering signals that are not exactly at the IF frequency will be rejected.

Sealing the filter prevents moisture and temperature changes from affecting the filter.

Q. 180. Describe, step-by-step, a proper procedure for aligning an FM double conversion superheterodyne receiver. 16.

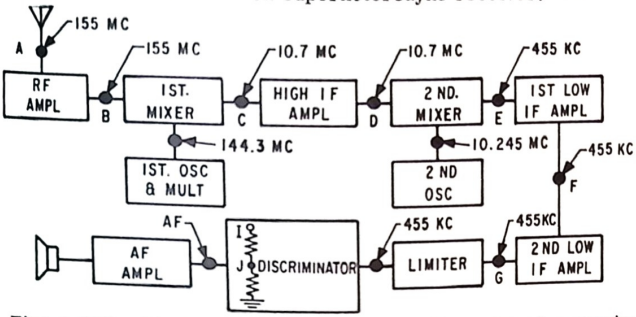


Figure 180. Block diagram of an FM double conversion receiver.

A. A double conversion FM superheterodyne is illustrated in Figure 180. A typical alignment procedure would be as follows:

(1) We start with the discriminator stage. A signal generator set at 455 Kc., unmodulated, is connected to the grid of the limiter stage (point G). A VTVM (with a center zero scale) is connected between the junction of the two output resistors of the discriminator (point J) and ground. The hot lead is connected to point J and the cold lead to ground. In this step, as well as all other steps in the alignment, the signal generator output is set as low as possible, just enough to give an adequate meter reading. The primary tuning slug or trimmer in the discriminator can is adjusted for maximum reading. The hot lead of the VTVM is then disconnected and the meter is set so that the zero reading is at the center of the scale. The hot lead of the VTVM is connected to point I and the secondary of the discriminator is adjusted to center zero. As the secondary slug is adjusted to either side of the correct zero point, the meter will read first to one side, then to the other. Thus, it is possible to check that we are at the correct zero point. We can check the discriminator linearity by varying the signal generator frequency equal amounts on both sides of 455 Kc. The meter reading should move equal amounts on both sides of center zero. If the linearity is off, the primary of the discriminator should be touched up.

The alignment of a ratio detector is slightly different from that of the discriminator just described. In the case of the ratio detector, we insert two equal resistors across the output. With the VTVM across both resistors, the primary of the discriminator transformer is peaked for maximum. Then with the VTVM between the junction of the two added resistors and the junction of the two output capacitors, we adjust the secondary for center zero. When this is done, the two resistors are removed.

(2) The VTVM is placed across the grid resistor of the limiter. The signal generator, at 455 Kc., unmodulated, is fed to the grid of the second low IF amplifier (point F). The primary and secondary of the IF transformer at point G are adjusted for maximum readings.

(3) The signal generator is moved to the grid of the first low IF amplifier (point E) and the primary and secondary of the IF transformer at point F are peaked for maximum.

(4) The signal generator is moved to the grid of the second mixer (point D) and the primary and secondary of the IF transformer at point E are peaked for maximum. The second oscillator is generally crystal controlled; however, its output trimmer can now be peaked for maximum.

(5) Set the signal generator to 10.7 Mc., unmodulated. Connect it to the grid of the high IF amplifier (point C). Peak the primary and secondary of the IF transformer at point D.

(6) Connect the signal generator to the grid of the first mixer (point B) and peak the primary and secondary of the IF transformer at point C. The first oscillator and its multipliers are now also peaked.

(7) The signal generator is now set to 155 Mc. (unmodulated). It is connected to the antenna terminals of the receiver. The tuned circuits of the RF amplifiers are peaked for maximum reading.

The receiver is now completely aligned.

Q. 181. Discuss the cause and prevention of interference to radio receivers installed in motor vehicles. 15.

A. Sparking causes interference to any receiver. Therefore, anything that causes sparks will cause interference. In a motor vehicle, this includes the spark plugs, generator brush sparking, distributor sparking, etc. This interference can be minimized by the following methods:

1. Use a shielded wire between the antenna and the receiver.
2. Put by-pass condensers across the generator, distributor points and switches.
3. Use suppressors at the spark plugs.
4. Shield the ignition wires.

Q. 182. Describe the difference between positive (P-type) and negative (N-type) semiconductors with respect to: 6.

(a) The direction of current flow when an external emf is applied.

(b) The internal resistance when an external emf is applied.

A. (a) The difference between conduction in an N-type and P-type semiconductor is due to the difference in electrical properties of the two types of semiconductors: The N-type semiconductor conduction is due primarily to the movement of electrons; whereas the P-type semiconductor conduction depends primarily on the movement of "holes" (positive carriers). Because the N-type semiconductor has electrons which are free to move when an

EMF is applied, current flows from the negative battery terminal through the semiconductor to the positive terminal.

P-type semiconductor conduction is due to the flow of "holes". A hole can be thought of as the absence of an electron and is, therefore, positively charged. Since positively charged bodies move to a negative point, the flow of current in a P-type semiconductor is from the positive battery terminal through the semiconductor to the negative battery terminal.

(b) The internal resistance of both P-type and N-type semiconductors is low in the direction of the flow of the majority current carriers. The resistance of both types may be decreased by adding impurities to the semiconductors or by increasing its temperature.

Q. 183. What is the difference between forward and reverse biasing of transistors? 6.

A. Forward bias refers to the polarity of the voltage required for maximum current flow. Reverse bias refers to the condition of little or no current flow.

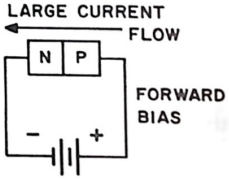


Figure 183A.

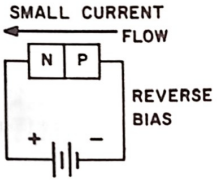


Figure 183B.

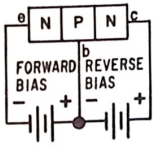


Figure 183C.

Figure 183A shows an NP junction with forward bias. Note the large current flow in the direction of the arrow. Figure 183B shows a reverse bias situation. The current flow is almost zero. Figure 183C shows two bias voltages hooked up to a transistor. One junction (the emitter-to-base junction) is forward biased, while the other junction (the base-to-collector) is reverse biased.

Q. 184. Show connections of external batteries, resistance load and signal source as would appear in a properly (fixed) biased common-emitter transistor amplifier. 10.

A. A fixed bias common-emitter transistor amplifier is shown in Figure 184. R_L is the load resistor and R_b is the bias resistor.

Q. 185. The following are excerpts from a transistor handbook describing the characteristics of a PNP alloy type transistor as used in a common-emitter circuit configuration. Explain the significance of each item. 10.

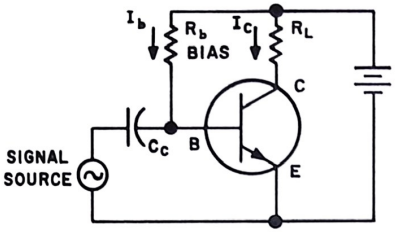


Figure 184. A fixed-bias common emitter transistor amplifier.

MAXIMUM AND MINIMUM RATINGS

(a) Collector-to-base voltage (emitter open)... -40 Max. volts
(b) Collector-to-emitter voltage
(Base-to-emitter volts = 0.5) ..... -40 Max. volts
(c) Emitter-to-base voltage ..... -5.0 Max. volts
(d) Collector current ..... 10 Max. ma.

TRANSISTOR DISSIPATION

(e) At ambient temperature of 25° C
For operation in free air ..... 120 Max. MW
(f) At case temperature of 25° C
For operation with heat sink ..... 140 Max. MW
(g) Ambient-temperature range:
Operating and storage .. .. -65 to + 100 C

A. (a) Collector-to-base voltage (Emitter open): This is known as the collector voltage. It is the maximum voltage that can be applied between the collector and the base without damaging the transistor.

(b) Collector-to-emitter voltage (Base-to-emitter voltage = 0.5). This voltage is the maximum collector-to-emitter voltage which can be applied with a forward bias of 0.5 volts. The forward bias develops a base current Ib which is not zero.

(c) Emitter-to-base voltage: For this PNP transistor, -5.0 volts corresponds to the most negative voltage which may be applied between the emitter and base terminals without damaging the transistor.

(d) Collector current: This is the maximum current which may flow for the particular load resistor and B+ supply given in this circuit. Thus, when the emitter-base junction is extremely forward biased, the collector-emitter voltage is nearly zero and all of the B+ voltage appears across the load.

(e) Transistor Dissipation at ambient temperature of 25°C for operation in free air: For this transistor which is

operating in free air, we may not permit a collector dissipation of more than 120 MW. Should a greater power be dissipated for any appreciable length of time, the transistor will be damaged due to overheating.

(f) Transistor Dissipation at case temperature of 25°C for operation with heat sink: As above, we may not permit more than 140 MW. of collector dissipation or else we may damage the transistor. The important point to note is that because we have used a heat sink, we may operate the transistor at a higher dissipation. This is, of course, due to the fact that the heat generated within the transistor is dissipated more rapidly by the metallic heat sink than by the air surrounding the transistor.

(g) Ambient-temperature range (operating and storage): This is the range of ambient temperatures in which this transistor may be operated and or stored without fear of damaging the unit because of thermal effects.

Q. 186. Draw a circuit diagram of a method of obtaining self-bias, with one battery, without current feedback, in a common-emitter amplifier. Explain the voltage drops in the resistors. 10.

A. Figure 186 illustrates a "collector-to-base" bias circuit. Both the collector current Ic and the base current, I_b flow through the load resistor R_L, developing the voltage V_{RL}. The voltage V_{RB} is determined by the flow of base current through resistor R_b.

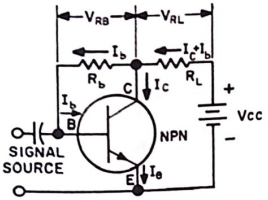


Figure 186. A common emitter amplifier.

Q. 187. Draw a circuit diagram of a common-emitter amplifier with emitter bias. Explain its operation. 10.

A. A circuit utilizing emitter bias is shown in Figure 187. Resistor Re stabilizes the circuit in the following manner: Should the collector current Ic increase due to temperature rise, the voltage across Re will increase since Ic flows through this resistor. This will increase the emitter-to-ground voltage. The net effect of this voltage increase is to decrease the base current which, in turn, reduces the collector current (Ic). Hence, the original collector current increase is counteracted.

The signal is applied across the base and emitter. The transistor provides amplification and the output is taken from the load resistor.

The output signal is 180° out of phase with the input signal. This differs from the common base amplifier where the output and input signals are in phase.

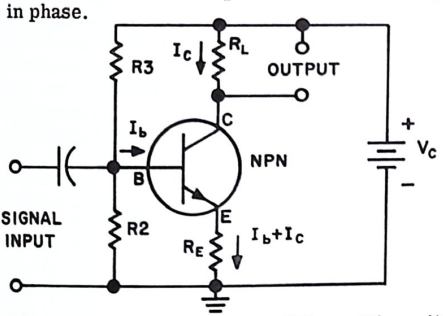


Figure 187. A common emitter amplifier with emitter bias.

Q. 188. The value of the alpha cutoff frequency of a transistor is primarily dependent upon what one factor? Does the value of alpha cutoff frequency normally have any relationship to the collector-to-base voltage? 10.

A. (a) The alpha cutoff frequency is defined as the upper frequency at which alpha (current gain of a transistor) decreases to 0.707 of its low frequency value. The alpha cutoff frequency depends primarily upon the physical thickness of the base. It also depends upon the semiconductor material in the base region. The formula for the alpha cutoff frequency is:

$$f\alpha co = \frac{0.38D}{W^2}$$

Where: $f\alpha co$ is the alpha cutoff frequency
W is the thickness of the base
D is a diffusion constant which depends on the semiconductor material in the base region.

It can be seen from the formula that the alpha cutoff frequency decreases as the base thickness increases.

(b) The alpha cutoff frequency is not directly dependent upon the collector-to-base voltage. However, there is a coincidental relationship between them. As we reduce the thickness of the base, the amount of voltage that may be applied between the base and collector must be reduced. Thus, as the alpha cutoff frequency is increased, the collector-to-base voltage must be reduced. Both of these factors must be considered in designing a transistor amplifier.

Q. 189. Why is stabilization of a transistor amplifier usually necessary? How would a "thermistor" be used in this respect? 10.

A. (a) Stabilization is necessary to insure that the amplifier continues to operate properly, despite changes in temperature and bias supply voltages.

The most critical change in a transistor's operating characteristics is caused by changes in the reverse saturation current (Ico) which flows through the base-to-collector junction. Ico is strongly dependent on temperature. (Ico approximately doubles for each 10^0 C rise in temperature). Therefore, if a circuit is stable, it must exhibit little change in operation with changes in Ico.

To a lesser degree, base-to-emitter voltage (Vbe) and Beta (B) are temperature dependent and can change the operating conditions. Changes in supply voltages also affect operation.

(b) As an illustration of how a thermistor may be utilized to improve stability, examine Figure 189. The circuit differs from Figure 187 in that R_E has been replaced by both R_E and thermistor R_T. The resistance of the resistor R_E increases with temperature. But the resistance of the thermistor R_T decreases with temperature. By the correct choice of resistor, R_E and thermistor R_T, the circuit becomes virtually independent of temperature.

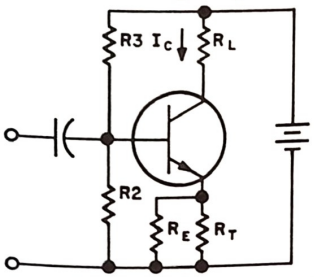


Figure 189. A transistor amplifier using a thermistor.

Q. 190. Draw simple schematic diagrams of the following transistor circuits and explain their principles of operation. Use only one voltage source; state typical component values for low power—10 Mc. operation:

(a) Colpitts-type oscillator. 12.
(b) Class B push-pull amplifier. 13.
(c) Common emitter amplifier. 13.
(d) A PNP transistor directly coupled to an NPN type. 10.

A. (a) Figure 190A illustrates a Colpitts oscillator. The values shown are for 10 Mc. operation. The output is taken from the tank circuit C1, L1. As is common in all Colpitts oscillators, feedback is accomplished through a

split capacitor arrangement consisting of C2 and C3. The value of these capacitors determines the amount of feedback. The feedback is from the collector to the emitter. The 1K resistor is the emitter bias and the combination of the 47K and 4.7K resistors is the base bias.

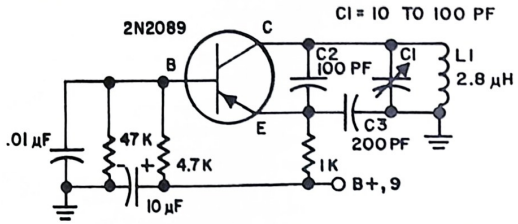


Figure 190A. A transistorized Colpitts-type oscillator.

(b) Figure 190B illustrates a Class B push-pull amplifier. It operates in much the same manner as a tube type amplifier. The input signal is fed to the tuned circuit L1, C1. From here it is applied to the bases of the transistors. The output is taken from the collectors and applied to the output tuned circuit C2, L2. As in tube amplifiers, each tube amplifies during one half of the cycle and is idle on the other half. Both halves combine in the output tuned circuit C2, L2. The 47K and 3K resistors provide base bias for the transistors and bias the transistors to cut-off for Class B operation. The 500 ohm resistor provides emitter bias and protects the transistors against thermal runaway.

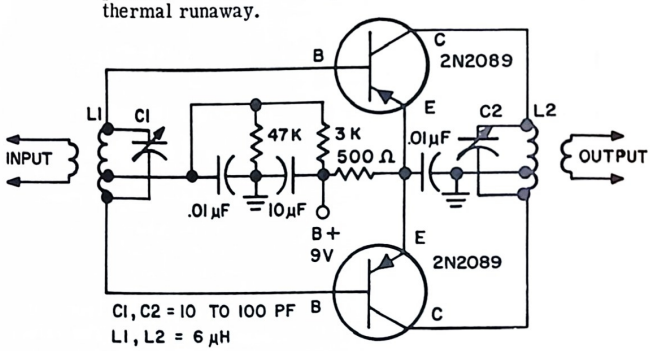


Figure 190B. A transistorized Class B push-pull amplifier.

(c) A common emitter amplifier for 10 Mc. operation is shown in Figure 190C. The basic explanation of the common emitter amplifier is discussed in Answers 186 and 187.

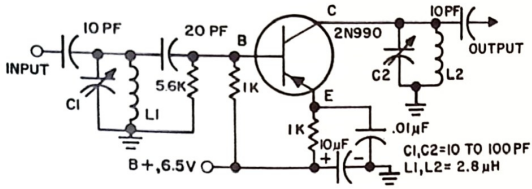


Figure 190C. A transistorized common emitter amplifier.

(d) Figure 190D shows an amplifier in which a PNP transistor is directly coupled to an NPN transistor. The incoming signal is fed to the base of T1. The amplified output of this transistor is taken from its collector and fed directly to the base of T2. The output of this stage is taken from the collector of T2. The gain of this configuration is greater than that of one transistor with two tuned circuits and is more stable than two ordinary stages. T1 sets the base bias for T2. This is because the collector current of T1 flows through R1, which is part of the base bias of T2.

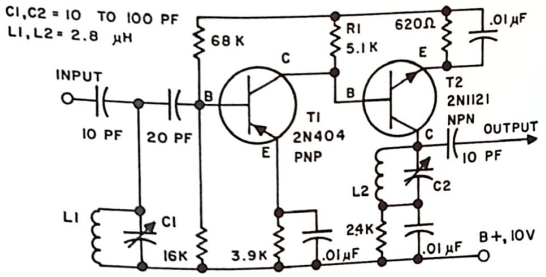


Figure 190D. A PNP transistor directly coupled to an NPN type.

Q. 191. Discuss etched-wiring printed circuits with respect to the following: 2.

(a) Determination of wiring breaks.

(b) Excessive heating.

(c) Removal and installation of components.

A. (a) A break in the copper-plated laminate can best be determined with an ohmmeter. Close physical inspection with the aid of a magnifying lens will locate most breaks. Be-

cause of the miniaturization in the electronics industry, a magnifying lens is an important tool in a serviceman's kit.

(b) Excessive heating should be avoided since it can cause the printed circuit board to buckle, or it can cause the copper to break away from the board, resulting in open circuits. A small-tipped soldering iron with a maximum of 25 watts should be used. Soldering should be done quickly and neatly to avoid damage to the board or the components. The iron should be clean and a good grade of solder should be used.

(c) A defective part is removed by clipping it from its leads. Apply heat to the soldered joints and quickly remove the pigtails with the aid of a long nose plier. If we are removing a part that we want to save, clamp small heat sinks between the solder joints and the part so that most of the heat is prevented from actually reaching the part.

When a component is installed, make certain that the joint is clean and the eyelet hole clear. Insert the leads, bend them to hold the part in place, solder quickly and neatly, clip off the excess wire and make certain that you have not accidently bridged some copper strips with excess solder. Heat sinks may be used in soldering transistors or other parts that are easily damaged by heat.

Q. 192. What is a junction tetrode transistor? How do they differ from other transistors in base resistance and operating frequency? 10.

A. (a) A junction tetrode transistor is similar to an ordinary junction transistor except that two leads instead of one are connected to the base region. They are connected to opposite sides of the base region and a biasing potential is applied between the two terminals.

(b) The junction tetrode transistor exhibits considerably less base resistance and a much higher maximum allowable operating frequency than the ordinary junction transistor.

Q. 193. Explain the voltage and current relationships in a one wavelength antenna; one-half wavelength (dipole) antenna; one-quarter wavelength "grounded" antenna. 17.

A. (a) General: A resonant antenna (an antenna not terminated) will have standing waves of voltage and current along its length, Wherever a voltage maximum appears, a current minimum exists and vice versa. A current minimum and voltage maximum will always appear at the free end or ends of such an antenna.

(b) For an antenna one wavelength long, the current is minimum at both ends and at the center.

(c) For a half-wavelength antenna, the current is minimum at the ends.

(d) A quarter-wavelength "grounded" antenna is operated as a vertical antenna. The ground acts as the other quarter-wave to form a one-half wavelength antenna. Once again a minimum current and maximum voltage will appear at the free end (top) of the antenna. At the usual feed point or ground end a current maximum occurs.

Q. 194. What effect does the magnitude of the voltage and current, at a point on a 1/2 wavelength antenna in "free space" (a dipole) have on the impedance at that point? 17.

A. The impedance at any point of a half-wave antenna is equal to the voltage divided by the current. In a half-wave antenna, the impedance is low at the center (50 to 72 ohms is common) and high at the ends.

Q. 195. How is the operating power of an AM transmitter determined using antenna resistance and antenna current? 17.

A. The operating power is determined by multiplying the square of the antenna current by the antenna resistance.

Q. 196. What kinds of fields emanate from a transmitting antenna and what relationships do they have to each other? 17.

A. Two fields emanate from the antenna. One is the electric field and the other is the magnetic field. The fields are at right angles to each other.

Q. 197. Can either of the two fields that emanate from an antenna produce an EMF in a receiving antenna? If so, how? 17.

A. The energy emitted by the transmitting antenna takes the form of an electric field AND a magnetic field. These fields are "polarized" at right angles to each other and both are perpendicular to the line of travel. The electric wave is parallel to the transmitting antenna. If the receiving antenna is also parallel to the transmitting antenna, the EMF induced in the receiving antenna will be maximum; therefore, the received signal will be the strongest possible.

Theoretically speaking, it is possible for either of the two fields to produce an EMF in the receiving antenna. This is so because either field will automatically cause the other field to be present. Practically speaking, both fields are always present in a radiated wave.

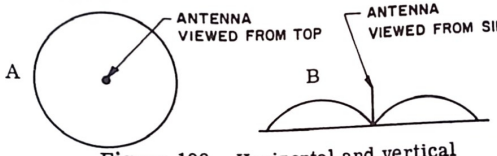


Figure 198. Horizontal and vertical radiation patterns of a 1/4 wave antenna.

Q. 198. Draw a sketch and discuss the horizontal and vertical radiation patterns of a 1/4 wave vertical antenna. Would this also apply to a similar type of receiving antenna? 17.

A. (a) Figure 198A illustrates the horizontal pattern of a quarter wave vertical antenna. It has an omnidirectional pattern; that is, it radiates equally well in all horizontal directions.

Figure 198B illustrates the vertical pattern of a quarter wave vertical antenna. It radiates well at low angles to the earth, but radiates very poorly directly above it.

(b) These same principles and patterns apply to receiving antennas.

Q. 199. Describe the directional characteristics, if any, of horizontal and vertical loop antennas. 17.

A. (a) A horizontal loop antenna radiates and receives well in all horizontal directions. It has minimum radiation and reception in a vertical direction.

(b) The vertical loop antenna has maximum radiation and reception off the ends of the loop, but it has minimum radiation and reception in directions broadside to the plane of the loop.

Q. 200. In speaking of radio transmissions, what bearing do the angle of radiation, density of the ionosphere and frequency of emission have on the length of the skip zone? 17.

A. The bending of a signal by an ionized region of the atmosphere is sketched in Figure 200.

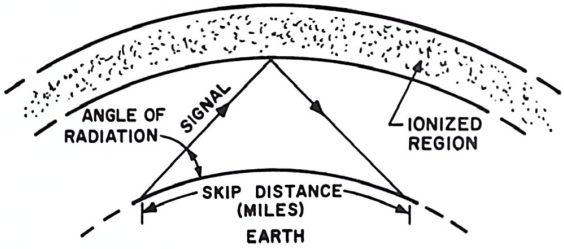


Figure 200. Relation of radio signal and "skip" distance.

(a) As the angle of radiation is increased, the skip distance decreases.

(b) A more dense ionosphere will result in a shorter skip distance.

(c) Higher frequencies will result in longer skip distances.

It should be noted that the above statements are highly oversimplified. For example, it should be realized that if the frequency is raised above a critical value, known as the maximum usable fre-

quency (MUF), no skip occurs. This is due to the fact that the signal penetrates the ionized region and never returns to earth.

Q. 201. Why is it possible for a sky-wave to "meet" a ground wave 180 degrees out of phase? 17.

A. The two waves leave the antenna in step or in phase and travel outward from the antenna at the speed of light. The sky wave takes an indirect path to the receiving antenna and therefore, travels a greater distance. If this difference in distance is greater by an odd multiple of one-half wavelengths, the two waves will arrive at the antenna 180 degrees out of phase and (if the magnitudes of the two waves are nearly equal) severe fading will occur.

Q. 202. What is the relationship between operating frequency and ground-wave coverage? 17.

A. The term "ground wave" includes the surface wave, the ground-reflected wave and the direct wave, as shown in Figure 202. Since the "ground reflected" and "direct" components of the ground wave are lost as the earth curves, the "surface wave" is the important part of the ground wave. It diminishes rapidly with increasing frequency. Above 3 Mc., the surface wave is of little value for communication.

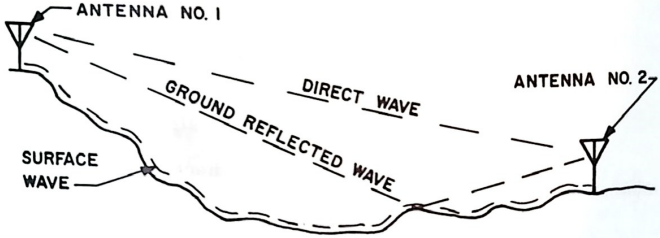


Figure 202. Relationship of radio signal to earth's surface.

Q. 203. Explain the following terms with respect to antennas (transmission or reception): 17 (except (g) which is 4.)

(a) Field strength
(b) Power gain
(c) Physical length
(d) Electrical length
(e) Polarization
(f) Diversity reception
(g) Corona discharge

A. (a) Field strength is the amount of electric field due to a transmitting antenna at a specific point in space. One volt per meter of field strength represents one volt induced into a wire that is one meter long.

(b) Power gain is the ratio of the power of a given antenna to a reference antenna. The reference antenna is usually a one-half wave dipole with the same polarization as the given antenna. Power gain is measured in the optimum

direction of the radiation of the given antenna.

(c) Physical length is the actual measured length of an antenna for a required frequency. If an antenna were ideal, its physical length would be the same as its calculated electrical length. However, the properties of the antenna conductor as well as the insulators cause the "non-ideal" antenna to be somewhat shorter than the calculated electrical length.

(d) The electrical length of an antenna is the length of an ideal antenna for a given frequency. This length is greater than the physical length as discussed in (c) above.

(e) A radio wave establishes perpendicular electrical and magnetic fields in space. Polarization is determined by the orientation of the electric field. As an example, a horizontally polarized antenna would have an electric field directed horizontally and a magnetic field directed vertically.

(f) Diversity reception is a radio receiving technique that makes use of several antennas to combat the problem of a fading signal. In the range of 2 to 30 Mc., antennas placed 3 to 10 wavelengths apart will exhibit the following in regard to fading: a signal received at either antenna (from the same transmitting source) will fade independently of the signal received at the other antenna. Consequently, if the two antennas are connected to an automatic switching device which connects the stronger of the two signals at any instant to the receiver, fading effects will be reduced. This technique is often termed "space diversity".

(g) Corona discharge is an electrical discharge from a high voltage point into the atmosphere. It is usually purple in color and accompanied by a hiss. It can occur from the antenna itself due to atmospheric conditions. A high potential generated by electric fields on a moving airplane may cause discharge from sharp points on the plane into the atmosphere, radiating this to a nearby receiving antenna as static.

Q. 204. What would constitute the ground-plane if a 1/4 wave grounded (whip) antenna, 1 meter in length, were mounted on the metal roof of an automobile; mounted near the rear bumper of an automobile? 17.

A. If the antenna were mounted on the roof of the car, the roof would serve as the ground-plane of the antenna. If it were located near the rear bumper, the bumper and possibly a portion of the car body would be the ground-plane.

The bumper mounted antenna would have a horizontal radiation pattern which would be quite directional, whereas the roof mounted antenna would have a fairly symmetrical pattern.

Q. 205. Explain why a "loading coil" is sometimes associated with an antenna. Under this condition, would absence of the coil mean a capacitive antenna impedance? 17.

A. A loading coil is added to increase the electrical length of the antenna and thereby lower its resonant frequency. If the "loaded" antenna is operating properly, removing the loading coil will cause the antenna impedance to become capacitive at the original frequency.

Q. 206. What radio frequencies are useful for long distance communications requiring continuous operation? 17.

A. The frequencies from 20 Kc. to 400 Kc. provide dependable communication because ionospheric reflection is both effective and fairly constant. In addition, ground wave attenuation is negligible.

Q. 207. What type of modulation is largely contained in "static" and "lightning" radio waves? 16.

A. Amplitude modulation is the principal form of modulation which occurs in static and lightning radio waves.

Q. 208. Will the velocity of signal propagation differ in different materials? What effect, if any, would this have on wavelength or frequency? 17.

A. The propagation velocity is slower in solids than in free air. This fact is often expressed by "velocity factor" (K) which is numerically slightly less than 1. Therefore: $V = KC$

Where: V = the velocity in the solid
K = velocity factor
C = is the velocity of an electromagnetic wave in free space

The wavelength is equal to the velocity divided by the frequency. As the velocity is reduced, the wavelength is reduced proportional to the velocity. The frequency remains unchanged. This explains the fact that the physical length of an antenna is shorter than the electrical length (see Question 203).

Q. 209. Discuss series and shunt feeding of 1/4 wave antennas with respect to impedance matching. 17.

A. An example of series tuning of a 1/4 wave ground-plane occurs when such an antenna is placed at the proper height for its radiation resistance to correspond to the transmission line impedance. See Figure 209A.

For example, if the antenna is 0.32 wavelength above ground, the radiation resistance will be 52 ohms. Consequently, 52 ohm coaxial cable will match the antenna. However, the antenna may not be resonant at this height. Hence a series capacitor is connected to tune the antenna so that the antenna presents a purely resistive load to the 52 ohm coaxial cable.

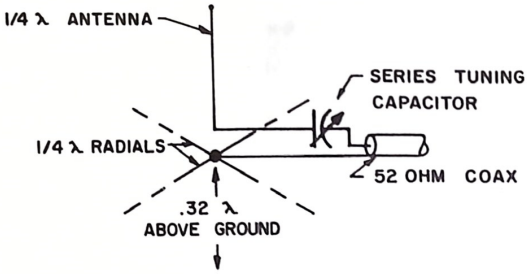


Figure 209A. A series tuned quarter wave antenna.

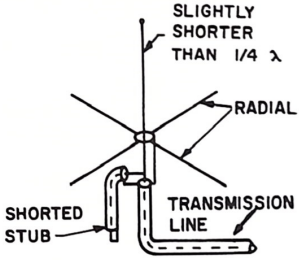


Figure 209B. A shunt tuned quarter wave antenna.

Figure 209B illustrates an example of shunt tuning a 1/4 wave ground-plane antenna. The vertical radiator is slightly shorter than 1/4 wave. Consequently, it presents a capacitive-reactive load to the transmission line. A shorted stub made of transmission line is shunted across the terminals. The stub length is so chosen that it is inductive and hence tunes the antenna so that it presents a purely resistive load to the transmission line.

Q. 210. Discuss the directivity and physical characteristics of the following types of antennas: 17.
(a) Single loop (b) V-beam (c) Corner-reflector
(d) Parasitic array (e) Stacked array

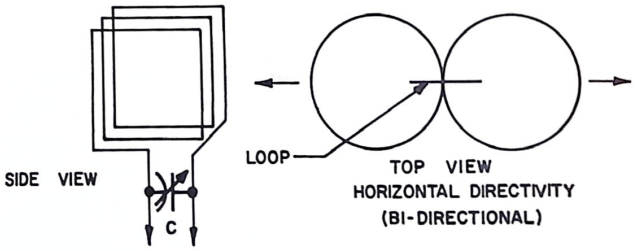


Figure 210A. A loop antenna with its horizontal pattern.

A. (a) A loop antenna is usually formed by coiling a length of wire into a large loop so that the ends of the wire are close together. (See Figure 210A). A vertically mounted loop is bi-directional and often is utilized in direction-finding equipment operating at low frequencies (200 to 500 Kc.). A horizontally-mounted loop is omnidirectional).

(b) A V-beam consists of two radiators placed horizontally forming a "V". (See Figure 210B). Gain is determined by the length of the radiators and the apex angle. As an example, with each leg 2 wavelengths long and an apex angle of 75°, gain is approximately 4 db. over a reference dipole. The gain of the V-beam is bi-directional.

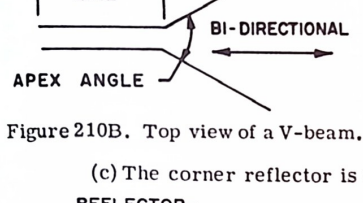


Figure 210B. Top view of a V-beam.

(c) The corner reflector is a variation of the parasitic antenna in which the reflector is formed in the shape of a "V". (See Figure 210C). The reflector may be a solid sheet or screen or it may be formed from parallel tubing. Its gain exceeds most other forms of parasitic arrays. 12 db. gain over a reference dipole is obtainable with an apex angle of 60°. This type of antenna is unidirectional as shown in Figure 210C.

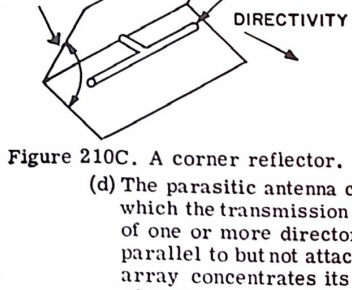


Figure 210C. A corner reflector.

(d) The parasitic antenna consists of a radiating element to which the transmission line is attached and a combination of one or more director and reflector elements placed parallel to but not attached to the radiator. The parasitic array concentrates its field in one direction. The gain of this type of antenna becomes greater as more elements are added.

(e) The stacked array consists of several antennas fed in phase with each other. They may be stacked in a vertical plane or a horizontal plane. Higher power gains are achieved when antennas are stacked.

Q. 211. Draw a sketch of a coaxial (whip) antenna; identify the positions and discuss the purposes of the following components: 17.

(a) Whip (b) Insulator (c) Skirt
(d) Trap (e) Support mast (f) Coaxial line
(g) Input connector

A. A coaxial antenna is illustrated in Figure 211.

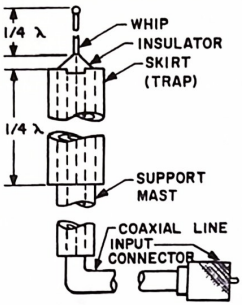


Fig. 211. A coaxial whip antenna.

(a) The whip forms the upper half of a 1/2 wave, vertically-polarized antenna. The center conductor of the coaxial line connects to the whip.

(b) The insulator serves as a support for the whip.

(c) The skirt acts as a 1/4 wave radiator.

(d) The skirt acts as a trap in that it prevents currents from circulating on the upper 1/4-wave of the coaxial line. If these currents were allowed to flow, they would impair the radiation capabilities of the antenna.

(e) The support mast is the mount for the antenna. If it is a conductor and does touch the skirt, such contact should occur only at the upper junction of the outer conductor of the coaxial line and the skirt.

(f) The coaxial line serves to couple the antenna to the receiver and transmitter.

(g) The input connector facilitates the electrical connection between the antenna and coaxial cable.

Q. 212. Why are insulators sometimes placed in antenna guy wires? 17.

A. Insulators are sometimes placed in antenna guy wires to prevent them from acting as absorbers or radiators of the RF energy. The insulators break up the guy wires so that they do not form resonant lines which can interfere with the signal.

Q. 213. What is meant by the "characteristic" (surge) impedance of a transmission line; to what physical characteristics is it proportional? 17.

A. The characteristic or surge impedance is the ratio of the voltage to current of a wave travelling along an infinite transmission line. This impedance is determined by the capacitance (c) per unit length and the inductance (L) per unit length of the transmission line.

A convenient and reasonably accurate way of computing the characteristic impedance of an air-insulated parallel-conductor line is to make use of the following formula:

$$Z_0 = 276 \log \frac{b}{a}$$

Where: Z_0 = characteristic impedance
b = center-to-center distance between conductors
a = radius of the conductors

Q. 214. Why is the impedance of a transmission line an important factor with respect to matching "out of a transmitter" into an antenna? 17.

A. The purpose of a transmission line is to transfer radio frequency energy from the transmitter to the antenna. However, since every conductor is also a radiator of energy, the principal consideration is to reduce the radiation of energy from the transmission line to the lowest value. If radiation from the transmission line is to be minimized, the standing-wave-ratio must be as close to 1:1 as possible. This condition is fulfilled when the transmitter and the antenna offer terminal impedances equal to the impedance of the transmission line.

Q. 215. What is meant by "standing waves"; "standing-wave-ratio (SWR)" and "characteristic impedance" as referred to transmission lines? How can standing waves be minimized? 17.

A. If voltage measurements on points along a transmission line are taken, a voltage plot can be drawn as shown in Figure 215. If the transmission line is not terminated in its characteristic impedance, the voltage wave will repeat at 1/2-wave intervals as shown in the figure. This voltage wave does not change with time, which explains why it is termed a "standing" wave. Notice that the current is also a standing wave. However, it is 180° out of phase with the voltage standing wave. If the transmission line should be terminated in its characteristic impedance, then the voltage and the current will both be constant values all down the line; hence no standing waves will exist.

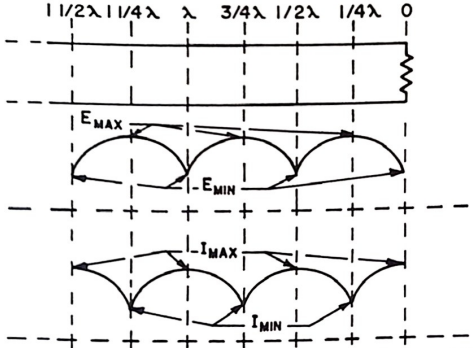


Figure 215. I and E graphs of standing waves on a transmission line.

The standing wave ratio (SWR) is the ratio of the maximum voltage to the minimum voltage along the transmission line. Maximum current to minimum current yields the same ratio.

Characteristic Impedance is explained in Question 213.

Standing waves can be minimized by terminating the line in its characteristic impedance.

Q. 216. If standing waves are desirable on a transmitting antenna, why are they undesirable on a transmission line? 17.

A. Standing waves on a transmission line means that radiation of energy is occurring along the line. This is undesirable since the function of the line is to transfer energy to the antenna without radiating. The antenna is the only element in the system that is supposed to radiate.

Q. 217. What is meant by "stub-tuning"? 17.

A. In order to eliminate standing waves on a transmission line, the load on the line must be matched to the line. A stub is a short section of transmission line, placed at a specific point on the line near the load end to effect this match. The length of the stub and its point of connection to the line depend on the relation between the characteristic impedance of the transmission line and the terminal impedance of the antenna.

Q. 218. What would be the considerations in choosing a solid-dielectric cable over a hollow pressurized cable for use as a transmission line? 17.

A. Solid dielectric cable is flexible and, therefore, easier to install than the hollow pressurized cable. It also is less expensive. On the other hand, since the hollow pressurized cable has lower losses, it is a more efficient transmission line.

Q. 219. Draw a simplified circuit diagram of a grid-dip meter; explain its operation and some possible applications. 18.

A. The grid dip meter shown in Figure 219 is essentially a Hartley oscillator circuit, tuned by a capacitor. A calibrated dial, fastened to the capacitor shaft, indicates the frequency to which the oscillator is tuned. The frequency band is determined by the plug-in coil in use.

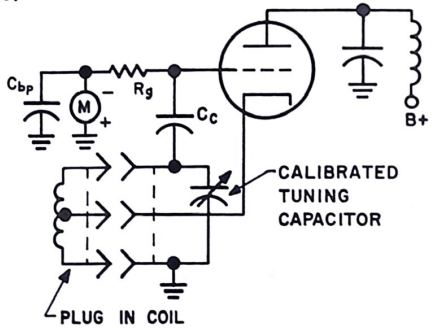


Figure 219. A grid-dip meter.

When the coil is coupled to a resonant circuit tuned to the same frequency as the grid dip meter, some of the oscillator energy will be absorbed by the resonant circuit. This causes the grid current to decrease, and hence the meter needle will dip.

The grid-dip meter becomes an absorption wavemeter in the following manner: If plate voltage is removed from the grid dip meter, then the oscillator tube becomes a rectifier and the meter will deflect only when energy is absorbed from a radiating source.

The grid dip meter is useful for measuring the frequency of L-C circuits and antennas. As an absorption wavemeter, it can be used to locate parasitic oscillations in transmitters. It can also function as a test oscillator.

Q. 220. Draw a simplified circuit diagram of an absorption wavemeter (with galvanometer indicator); explain its operation and some possible applications. 18.

A. An absorption-type wavemeter consists of a tuned circuit (a coil and variable condenser) and an RF indicator. The coil is loosely coupled to the circuit under measurement and the condenser is varied until the indicator reads maximum. The frequency is then read on the calibrated scale of the variable condenser. The absorption wavemeter is used to measure the frequency of the signal at any of the RF stages in a transmitter. It may also be used to find the frequency of spurious oscillations in a transmitter.

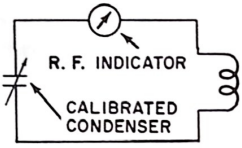


Figure 220. An absorption wavemeter.

Q. 221. Draw a block diagram, showing only those stages which would illustrate the principle of operation of a secondary frequency standard. Explain the functions of each stage. 18.

A. The principal circuits of a secondary frequency standard are shown in block diagram form in Figure 221. The crystal controlled

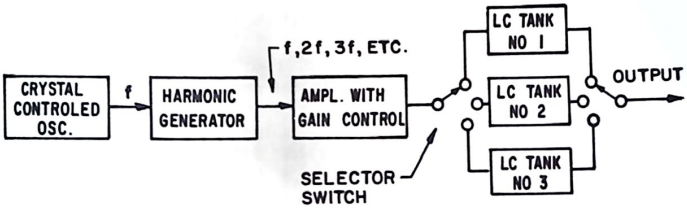


Figure 221. Block diagram of a secondary frequency standard.

oscillator produces a stable RF signal at a fixed fundamental frequency. The harmonic generator develops signals at multiples of the fundamental frequency of the crystal controlled oscillator. The fundamental frequency and its harmonics are amplified by the next stage and the signal amplitude is varied by the gain control. Different L-C tank coils may be switched into the circuit to allow a choice of harmonic frequencies.

Q. 222. Draw a block diagram of a Heterodyne Frequency Meter, which would include the following stages: 18.

CRYSTAL OSCILLATOR; CRYSTAL OSCILLATOR HARMONIC AMPLIFIER; VARIABLE FREQUENCY OSCILLATOR; MIXER; DETECTOR AND AF AMPLIFIER; AF MODULATOR

Show RF-Input and RF, AF, and Calibration-Outputs. Assume a band-switching arrangement and a dial having arbitrary units, employing a vernier scale.

(a) Describe the operation of the meter.
(b) Describe, step by step, how the crystal could be checked against WWV, using a suitable receiver.
(c) Under what conditions would the AF modulator be used?
(d) Describe, step by step, how the unknown frequency of a transmitter could be determined by use of headphones; by use of a suitable receiver.
(e) What would be meant by calibration check-points; when should they be used?
(f) If in measuring a frequency, the tuning dial should show an indication between two dial-frequency relationships in the calibration book, how could the frequency value be determined?
(g) How could this meter be used as an RF generator?
(h) Under what conditions would it be necessary to recalibrate the crystal oscillator?

A. (a) The operation of the Heterodyne Frequency Meter is based on the principle of mixing two signals together to produce a new "difference frequency". If one of the two signals is known and if we can adjust this known signal so that the difference between the two signals is zero, then the unknown frequency is the same as the known frequency.

Figure 222 illustrates a Heterodyne Frequency Meter. It operates as follows: With the switch in position #2, the unknown signal, which is fed to the RF input terminal, passes to the mixer. At the same time, the variable frequency oscillator, which has an accurately calibrated dial, generates a signal which is fed to the mixer. The two signals mix or "beat" together to produce the sum

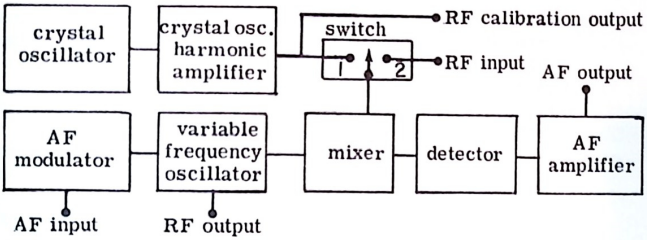


Figure 222. A Heterodyne-frequency meter.

and difference of the two signals. The two new signals, in addition to the two original signals, are fed to the detector which is tuned to choose only the difference frequency. As the variable frequency oscillator is tuned close in frequency to the incoming unknown signal, the difference is in the audio frequency range. This audio frequency difference is amplified in the AF amplifier and can be heard on the speaker or headsets at the output of the AF amplifier. As the frequency of the variable frequency oscillator (VFO) approaches the frequency of the unknown signal, the audio frequency becomes lower and lower. When the two frequencies are the same, the difference is zero and we hear nothing. This process is called "zero beating". Tuning the VFO to either side of the "zero" point produces an audible sound. Thus it is easy to find the "zero" point. When we find the zero point, we note the reading on the dial and we look up the reading in the manual that comes with the meter in order to find the frequency.

To insure that the VFO dial is accurate, we can turn the switch to position #1 and compare the VFO with the output of the crystal oscillator. The crystal oscillator usually generates a 1.0 Mc. signal. The harmonic amplifier will amplify the 1.0 Mc. signal or any of its harmonics. If the VFO is not accurate, its dial or a trimmer can be adjusted. To check the accuracy of the crystal oscillator, its output can be compared with station WWV which transmits a highly accurate signal at 2.5, 5, 10, 15, 20 and 25 Mc.

(b) Carefully tune a receiver to one of the WWV signals. Loosely couple the RF Calibration output of the meter to the antenna of the receiver. Choose the harmonic of the crystal oscillator that is the same as the WWV signal. The two RF signals should beat together in the receiver

and an audible note will be heard when the frequencies are close to each other. We then zero beat to determine the accuracy of the oscillator. If the crystal oscillator is not accurate, we can adjust a trimmer to make it exact.

(c) The AF modulator is used to modulate the VFO signal so that an audible signal will be heard on a receiver when it is tuned to the VFO frequency. We can use it to calibrate the receiver dial or for any other test purposes where an accurate modulated RF signal is required.

(d) 1). Determining the unknown frequency of a transmitter by use of headphones has been fully described in (a) above.
2). A suitable receiver can be used to determine a transmitter frequency in the following manner: The receiver is tuned to the unknown frequency. The RF output of the VFO is loosely coupled to the receiver. The two signals are zero-beat in the receiver. We then read the dial of the VFO and use the manual to find the equivalent frequency.

(e) 1). The calibration check points are points on the VFO dial that correspond to the harmonic multiples of the frequency of the crystal-controlled oscillator. They are zero-beat points where the frequency of the VFO is equal to the crystal oscillator frequency or its multiple. By the use of headsets, we can hear the zero-beat at the check points and thereby know the accuracy of the meter.
2). We should determine the accuracy of the meter with the calibration check points each time the meter is used.

(f) We determine the actual frequency by a process called "interpolation". An example will illustrate how this works. Let us assume that the dial reads 25.6. The manual tells us that 25 is equal to 40 Mc. and 26 is equal to 42 Mc. We must figure out what frequency 25.6 is equal to. We can see that one full unit of the dial is equal to 2 Mc. Therefore, 0.1 of a unit on the dial is equal to 0.2 Mc. Then 0.6 of a unit is 6 x 0.2 Mc. or 1.2 Mc. We add this to 40 Mc. to tell us what 25.6 Mc. is equal to. It is 41.2 Mc.

(g) The variable frequency oscillator is actually an RF generator. It is easily calibrated for accuracy and it can also be tone modulated. The output, taken from the RF output terminal, can be used for receiver alignment.

(h) The crystal oscillator should be re-calibrated at the following times:
1). Whenever a part (or batteries) is changed.
2). On a periodic basis - such as once every two weeks.
3). If it is transported or carried from one location to another.
4). Under severe climatic changes.

Q. 223. Draw a block diagram of an FM Deviation (Modulation) meter which would include the following stages: 16.

MIXER IF AMPLIFIER LIMITER
DISCRIMINATOR PEAK READING VOLTMETER

(a) Explain the operation of this instrument.

(b) Draw a circuit diagram and explain how the discriminator would be sensitive to frequency changes rather than amplitude changes.

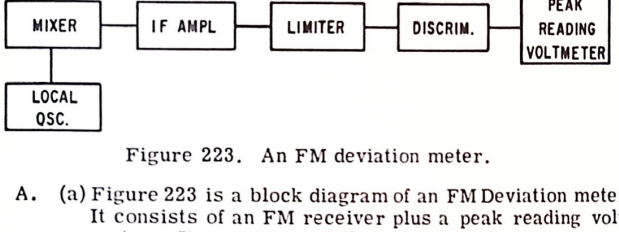


Figure 223. An FM deviation meter.

A. (a) Figure 223 is a block diagram of an FM Deviation meter. It consists of an FM receiver plus a peak reading voltmeter. It operates as follows:
The signal to be checked is fed into the mixer where it combines with the signal from the local oscillator. The difference between the two signals is the IF signal which is amplified in the IF amplifier stage. The signal is then passed on to the limiter stage where all amplitude variations are removed. The signal then goes to the discriminator where the frequency variations are converted to amplitude variations. These amplitude variations represent the original audio signal that modulated the carrier (causing the frequency of the carrier to shift or deviate). The audio signal is then passed to a circuit and meter which reads its peak voltage. This peak voltage meter may be calibrated in frequency and thereby read the actual frequency deviation. As the frequency deviation increases, the amplitude of the output voltage of the discriminator increases and the peak reading voltmeter will indicate a larger frequency deviation.

(b) See Answer 177D for the diagram and explanation of a Discriminator.

Q. 224. Describe a usual method (and equipment used) for measuring the harmonic attenuation of a transmitter. 13.

A. A simple way of measuring the harmonic attenuation of a transmitter is to use a field strength meter and compare the transmitter's output at its fundamental frequency and at the various harmonic frequencies.

An accurate field strength meter, calibrated in decibels and de-

signed for this purpose, should be used. The meter should be placed at least several wavelengths away from the transmitter. Improper readings will result if the meter is placed within one wavelength from the transmitter. Also, if the field strength meter is too close to the transmitter, the transmitter's fundamental frequency will tend to overload the meter.

With the transmitter turned on, a reading in decibels should be taken at the fundamental frequency. The meter should then be tuned to the second harmonic, the third harmonic, etc. Readings are taken at the various harmonics and compared to the reading at the fundamental frequency. The difference between readings tells us the amount of attenuation that the various harmonics have.

Q. 225. Why is it important that transmitters remain on frequency and that harmonics be attenuated? 13, 18.

A. If a transmitter shifts its frequency, it will cause interference to adjacent channels. It will also be difficult for the receiving station to copy the signal. Harmonics cause interference to other stations and should be attenuated.

Q. 226. How does a primary cell differ from a secondary cell?1.

A. A secondary cell can be recharged and used again after it is run down. A primary cell cannot be recharged.

Q. 227. What is the chemical composition of the electrolyte of a lead-acid storage cell? 1.

A. A dilute solution of sulphuric acid in distilled water.

Q. 228. Describe the care which should be given a group of storage cells to maintain them in good operating condition. 1.

A. The following steps should be taken to keep a group of storage cells in good operating condition:

(1) The cells should be checked frequently to make certain that they are fully charged.
(2) The level of the solution should be kept up to normal by adding distilled water when necessary.
(3) If a cell is discharged, it should be charged immediately.
(4) Adequate ventilation must be provided.
(5) Acid should be added only when some has been lost due to spilling.
(6) The cells should be kept on trickle charge when not in use.
(7) The cells should not be charged or discharged at too high a rate.
(8) The exterior of the battery should be kept clean and the terminals should be coated with a thin layer of pure vaseline.
(9) Bad cells should be removed from the circuits.

Q. 229. What may cause "sulphation" of a lead-acid storage cell? 1.

A. Sulphation is the formation of excessive sulphate on the plates of the lead acid battery. This increases the internal resistance of the cell which, in turn, increases the heating (internal I^2R losses) inside the cells. Sulphation is caused by discharging the storage cell at an excessively high current rate or by discharging the battery too long before charging.

Q. 230. What will be the result of discharging a lead-acid storage cell at an excessively high current rate? 1.

A. (1) Excessive heating due to I^2R losses.
(2) Excessive sulphation.
(3) Buckling of the plates.
(4) Reduction of the capacity of the cell.

Q. 231. If the charging current through a storage battery is maintained at the normal rate, but its polarity is reversed, what will result? 1.

A. The battery will discharge instead of charge. If this is continued for too long a period of time, overheating and sulphation may result.

Q. 232. What is the approximate fully charged voltage of a lead-acid cell? 1.

A. 2.1 volts.

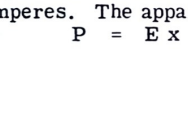
Q. 233. What steps may be taken to prevent corrosion of lead-acid storage cell terminals? 1.

A. The cell terminals should be kept clean and they should be coated with a thin layer of pure vaseline. The terminal connections should be tight.

Q. 234. How is the capacity of a battery rated? 1.

A. The capacity of a battery is generally rated in ampere-hours. In other words, the capacity will tell how many hours of useful life a battery or cell has if a certain amount of current is drawn from it. For example, if a battery is rated at 50 ampere-hours over a 10 hour period, it means that 5 amperes can be drawn for 10 hours.

Q. 235. What is "power factor"? Give an example of how it is calculated. Discuss the construction and operation of dynamotors. 4, 5.



A. Power factor is the ratio of the real power to the apparent power in a reactive circuit. An example will make this definition clear. Figure 235A shows an AC circuit with inductance and resistance.

By using the impedance formula, $Z = \sqrt{X_L 2 + R^2}$, we find the impedance to be 50 ohms. The current in the circuit is therefore, 3 amperes. The apparent power is found by using the formula:

$$P = E \times 1 = 150 \times 3 = 450 \text{ watts.}$$

However, we know that only the resistor consumes actual power. So we use the formula: $P = I^2 \times R$ to find the real power. $(3)^2 \times 30 = 270$ watts. Since the power factor is equal to $\frac{\text{real power}}{\text{apparent power}}$, the power factor in the above example is $\frac{270}{450}$ or 0.6.

A dynamotor is a combination of a motor and a generator in one unit. A common field is used and the two armatures are on a common shaft. Low voltage DC is fed to the motor portion and high voltage DC is taken from the generator section. Dynamotors are generally used to supply power in portable installations.

Because of the common field and common armature shaft, the voltage regulation is poor and the output voltage cannot be varied by the usual methods. A series resistor in the output circuit must be used to vary the output voltage.

Q. 236. List the comparative advantages and disadvantages of motor-generator and transformer-rectifier power supplies. 5, 7.

A. The advantages of a motor-generator power supply are:
(a) rugged construction. (b) rectifier tubes not required.
(c) ability to operate from AC or DC power sources.
(d) high ripple frequency, thus small filtering requirements.

The disadvantages of a motor-generator power supply are:
(a) frequent need for service, inspection and repair.
(b) high initial cost.
(c) occupies considerable space.
(d) sparking that causes RF interference.
(e) cannot obtain very high DC voltages.

The advantages of a transformer-rectifier power supply are:
(a) availability of a very high voltage.
(b) very little servicing required.
(c) low initial cost.
(d) compact, light and completely electronic.

The disadvantages of a transformer-rectifier supply are:
(a) unless modified, must operate from AC power source.
(b) tubes require occasional replacement.
(c) requires more filtering than motor-generator power supply.
(d) high vacuum type rectifier tube has poor regulation.

Q. 237. What determines the speed of a synchronous motor? An induction motor? A DC series motor? 5.

A. The speed of synchronous motors and induction motors are determined by the line frequency and the number of poles. The speed of a direct current series motor is determined mainly by the load.

Q. 238. Describe the action and list the main characteristics of a shunt DC generator. 5.

A. The shunt wound generator depends upon the residual magnetism of its field coil magnet for its operation. This residual mag-

netism induces a current in the rotating armature. A small part of this current will flow through its field which is across the armature. This increases the strength of the field which, in turn, increases the current flow in the armature. This building-up process is completed when the generator reaches its rated output.

The armature current is equal to the sum of the field current and the load current. The field current is small compared with the load current and is relatively constant for normal load variations. Thus, the armature current varies directly with the load. The field flux produced by the field current is normally constant so that the terminal voltage does not vary widely with load changes. Hence, the shunt wound generator delivers current in accordance with the load demand and maintains a constant output voltage.

Q. 239. Name four causes of excessive sparking at the brushes of a DC motor or generator. 5.

A. Some causes of excessive sparking are:

(1) dirty commutator
(2) worn out brushes
(3) motor overloaded
(4) brushes off neutral position
(5) motor started too rapidly
(6) open or short in armature coil

Q. 240. How may radio frequency interference, often caused by sparking at the brushes of a high-voltage generator, be minimized? 5.

A. RF interference caused by sparking at the brushes can be minimized by the use of bypass condensers across the brushes. It may be further reduced by the use of a low pass filter in the line.

Q. 241. How may the output voltage of a separately excited AC generator, at constant output frequency, be varied? 5.

A. This can be done by varying the current in the field coils with a rheostat. This reduces the strength of the magnetic field, which in turn, reduces the output of the generator.

Q. 242. What is the purpose of a commutator on a DC motor? On a DC generator? 5.

A. The purpose of the commutator on a direct-current motor is to periodically reverse the current flow in the armature so that it has the correct magnetic field for rotating. In a direct-current generator, the commutator acts as a rectifier and changes the output of the armature from alternating current to direct current.

Q. 243. What may cause a motor-generator bearing to overheat? 5.

A. Any of the following may cause this condition:

(1) insufficient lubrication
(2) continuous overloading
(3) a defect in the line feeding the oil to the bearing.

Q. 244. What materials should be used to clean the commutator of a motor or generator? 5.

A. The commutator should be cleaned with a regular commutator polishing agent, or with a piece of very fine sandpaper. Emery cloth should never be used because it contains metallic particles which can short-circuit the commutator.

Q. 245. If the field of a shunt wound DC motor were opened while the machine is running under no load, what would be the probable result(s)? 5.

A. An open field means a loss of counter-emf in the armature. This causes the armature to draw a large current and possibly burn out. Also, the motor would race itself and cause damage to itself because of the excessive speed.

Q. 246. Describe the physical structure of a klystron tube and explain how it operates as an oscillator. 19.

A. A klystron tube consists of a cathode, two grids in a cavity resonator, a "catching" area and a feedback loop. The electrons emitted by the cathode pass into an electric field that is established by the two grids in the cavity resonator. The high frequency field between the grids is parallel to the electron field, and accelerates and retards the electron flow in accordance with variations in the applied RF voltage. This velocity-modulated electron beam is then guided to a "drift-space" that is field-free, and where the faster-moving electrons overtake the slower-moving ones. The beam is thus separated into bunches and goes to a "catcher" area where the beam is passed between two grids. RF current that is created by the beam's bunching induces an RF voltage between the two grids. The cavity is made resonant at the beam's frequency, so that an oscillating field is established. The oscillations are induced by a feed-back loop between the buncher and the catcher cavities. The resonant frequencies and variations in the resonant frequency, are controlled by both the voltage on the electrodes and the shape of the cavities. Although the bunched beam has a current that is well-laden with harmonics, the high Q of the catcher cavity serves to eliminate the undesired harmonics, and to produce a pure wave.

Q. 247. Draw a diagram showing the construction and explain the principles of operation of a travelling-wave tube. 19.

A. The travelling wave tube (TWT) is used principally as an amplifying device in microwave transmitters. The principal components of the TWT are shown in Figure 247.

Low power microwave energy is applied at the input and travels down the helix towards the output. At the same time, electrons from the cathode are accelerated down the tube toward the collector. These electrons are formed into a narrow beam by the beam focusing magnets.

Amplification of the microwave signal traveling along the helix occurs due to interaction of the signal with the electron beam. The interaction causes the electrons to "bunch". That is, some of the electrons are retarded and some are accelerated so that the beam

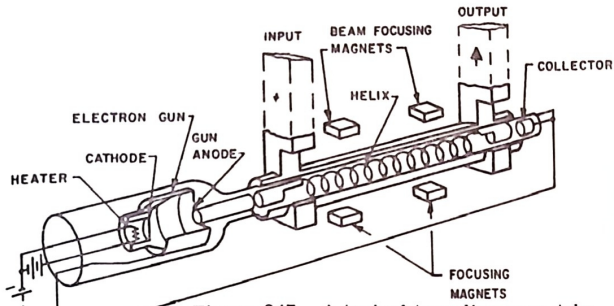


Figure 247. A typical traveling wave tube.

develops regions of both dense electron concentrations and sparse electron concentrations. The net effect of this bunching is to amplify the microwave signal traveling down the helix. Therefore, the signal emerging from the output is greatly amplified. Unlike the klystron tube, the TWT is a non-resonant device and is noted for broadband capabilities. It can amplify signals whose frequency range is approximately ten percent of its operating frequency.

Q. 248. Describe the physical structure of a multianode magnetron and explain how it operates. 19.

A. Basically, a magnetron is a diode with cylindrical electrodes placed in a uniform magnetic field. The simple magnetron consists of a filament cathode that is encompassed by a concentric anode. In the more complex, more efficient "split-anode" type magnetron, the anode cylinder is divided in half, thus causing a "split" anode. In the "multianode" magnetron, the anode is subdivided still further, with the resonant cavities of each anode coupled by slots to the single cathode region. The purpose of the multianode magnetron is to improve efficiency on the higher frequencies.

Q. 249. Discuss the following with respect to wave guides: 19.
(a) Relationship between frequency and size.
(b) Modes of operation.
(c) Coupling of energy into the wave guide.
(d) General principles of operation.

A. (a) The cross-sectional size of a waveguide is directly proportional to the wavelength and inversely proportional to the frequency of the signal traveling through it. In the case of a rectangular waveguide, the larger sides of the rectangle should be more than one-half the wavelength of the lowest frequency to be transmitted (0.7 to 0.8 is commonly used). The shorter sides should be approximately one-half the length of the longer sides. In the

case of a circular waveguide, the radius should be approximately one-third of the wavelength of the lowest frequency to be transmitted.

(b) Extremely high frequency energy travels through a waveguide in the form of electric and magnetic fields. There are a large number of ways in which the fields can arrange themselves. Each field configuration is called a "mode". There are two general groups of modes. One is called the "TRANSVERSE ELECTRIC" (TE) group and the other is called the "TRANSVERSE MAGNETIC" (TM) group. In the "TE" modes, ALL the ELECTRIC field components are in a plane transverse to the direction of propagation, and only one magnetic component is in the direction of propagation. In the "TM" modes, ALL the MAGNETIC field components are in a plane transverse to the direction of propogation and only one electric component is in the direction of propagation.

(c) Three basic methods are used to couple energy into the waveguide. These are the probe, loop and window methods. In the probe method, a straight piece of conductor is in the waveguide, radiating energy to the waveguide. The wire is parallel to the electric field it generates. In the loop method, a loop inside the waveguide couples energy to the waveguide. Coupling will be maximum when the plane of the loop is perpendicular to the magnetic lines. In the window method, energy from a cavity passes through a window or slot into the waveguide.

(d) Waveguides are generally rectangular or circular shaped metal tubes that are used to conduct, with minimum loss, extremely high frequency energy from one point to another. At these frequencies, the losses would be too great if ordinary transmission line were used.

The energy travels in the form of electromagnetic waves. The waves, both magnetic and electric, are propagated through the waveguide by means of reflections against its inner walls. Skin effect prevents the energy from escaping through the metal walls. The energy is injected into or removed from the waveguides by means of the coupling methods described above. The physical dimensions of a waveguide are determined by the frequency of the signal being transmitted.

Q. 250. Describe briefly the construction and purpose of a wave guide. What precautions should be taken in the installation and maintenance of a wave guide to insure proper operation? 19.

A. Wave guides are hollow rectangular or circular pipes that are used as transmission lines at extremely high frequencies (above 3,000 Mc.). They have low losses at these high frequencies. When installing the wave guide, make certain that no foreign matter is in-

side of it. Check opposing surfaces to be joined to insure that both are absolutely clean. Where flanges and bolts are used, line up the two pieces of the wave guide, making certain the gasket seats properly. Insert bolts carefully and tighten all nuts evenly.

Q. 251. Explain the principles of operation of a cavity resonator. 19.

A. Cavity resonators are hollow metal chambers that are closed on all sides. They form tank circuits at extremely high frequencies. These tank circuits are similar to the ordinary LC tank circuits in that they have electric and magnetic fields. Cavity resonators have a high Q at the very high frequencies.

Q. 252. How are cavities installed in vertical wave guides to prevent moisture from collecting? Why are long horizontal wave guides not desired? 19.

A. (a) Moisture can be prevented from collecting in waveguide sections by joining flanges tightly and using a gasket at each coupling flange. "Choke" joints should be used where possible. "Choke" joints are well designed mechanical couplings that maintain good electrical continuity.

(b) Long horizontal wave guides are not desirable because condensed moisture can accumulate in the waveguide. A moist waveguide will have losses and possible arcing.

Q. 253. Several problems of the following type will appear on the Element III examination. Candidates should be prepared to answer such diagram questions. As with all problems in Element III, answers are of the multiple choice type where the candidate is instructed to choose the best one of five given. 12, 14.

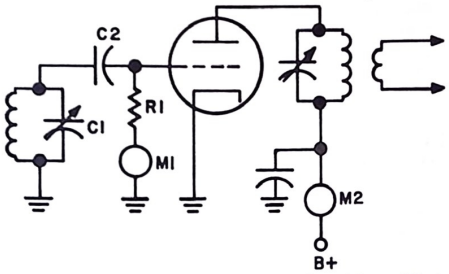


Figure 253. A tuned-plate, tuned-grid oscillator.

The above diagram represents a tuned-plate, tuned-grid oscillator.

1. If C_1 should short:
   (a) Meter M1 would read higher.
   (b) Meter M1 would read lower.
   (c) Meter M2 would read lower.

(d) Meter M2 would read 0.
(e) None of the above are true. Both meters would read normal.

2. If R1 should burn out:
(a) Meter M1 would read 0.
(b) Meter M2 would read lower.
(c) Meter M1 would read higher.
(d) Meter M2 would read higher
(e) Both (a) and (b) above are true.

A. The correct answer to question 1 is (b). If C1 should short, we would no longer have a tuned grid circuit and oscillation would cease. The grid is no longer driven alternately positive and negative. Thus, little if any grid current flows and meter, M1 will read zero or a very low value.

The correct answer to question 2 is (e). If R1 should burn out, the grid circuit will be open as far as DC is concerned. There will be little or no grid current flow. We will have a blocked grid effect. The grid will accummulate a high negative charge and reduce the plate current to zero or a very low value. M1 will therefore read zero and M2 will read zero or very low.

Q. 254. Define the following words or phrases: 21.

(a) authorized frequency
(b) carrier
(c) base station
(d) coast station
(e) earth station
(f) fixed station
(g) space station
(h) harmful interference
(i) land mobile service
(j) land station
(k) mobile service
(l) primary standard of frequency

A. (a) The authorized frequency is the frequency assigned to a station by the Commission and specified in the instrument of authorization.

(b) The carrier is the output of a transmitter when the modulating wave is removed. It may also be defined as the wave generated at a point in the transmitting system and subsequently modulated by the signal.

(c) A base station is a land station in the land mobile service carrying on a service with land mobile stations.

(d) A coast station is a land station in the maritime mobile service.

(e) An earth station is a station in the earth-space service located either on the earth's surface or on an object which is limited to flight between points on the earth's surface.

(f) A fixed station is a station in the fixed service, the fixed service being a service of radio communication between specified fixed points.

(g) A space station is a station in the earth-space service or the space service located on an object which is be-

yond, or intended to go beyond, the major portion of the earth's atmosphere and which is not intended for flight between points on the earth's surface.

(h) Harmful interference is any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with the Commission's Rules and Regulations.

(i) A land mobile service is a mobile service between base stations and land mobile stations, or between land mobile stations.

(j) A land station is a station in the mobile service not intended to be used while in motion.

(k) A mobile service is a service of radio communication between mobile and land stations, or between mobile stations.

(l) The primary standard of frequency for radio frequency measurements shall be the national standard of frequency maintained by the National Bureau of Standards, Department of Commerce, Washington, D. C. The operating frequency of all radio stations will be determined by comparison with this standard or the standard signals of Station WWV of the National Bureau of Standards.

Q. 255. What is the frequency range associated with the following general frequency subdivisions: 21.
(a) VLF (b) LF (c) MF (d) HF (e) VHF (f) UHF (g) SHF (h) EHF

A. (a) VLF - very low frequency - below 30 kilocycles (Kc.)
(b) LF - low frequency - 30 to 300 Kc.
(c) MF - medium frequency - 300 to 3,000 Kc.
(d) HF - high frequency - 3,000 to 30,000 Kc.
(e) VHF - very high frequency - 30 to 300 megacycles (Mc.)
(f) UHF - ultra high frequency - 300 to 3,000 Mc.
(g) SHF - super high frequency - 3,000 to 30,000 Mc.
(h) EHF - extremely high frequency - 30,000 to 300,000 Mc.

21.

Q. 256. What is meant by the following emission designations:
(a) A3 (b) A3A (c) A5C (d) F3 (e) F5 (f) P3D

A. (a) A3 stands for amplitude modulated telephony using both sidebands. This is the common type of emission used by the broadcast stations.

(b) A3A stands for amplitude modulated telephony using one sideband (single sideband) and a reduced carrier.

(c) A5C stands for the regular amplitude modulated television with its vestigial sideband emission.

(d) F3 stands for frequency (or phase) modulated telephony as used by the FM broadcast stations.

(e) F5 stands for frequency modulated television.

(f) P3D stands for pulse modulated telephony using amplitude modulated pulses.

Q. 257. What is the basic difference between type approval and type acceptance of transmitting equipment? 21.

A. Type approval contemplates tests conducted by Commission personnel, while type acceptance is based on data concerning the equipment submitted by the manufacturer or the individual prospective licensee.

Q. 258. Define the following phrases: 21.

(a) Authorized bandwidth.

(b) Bandwidth occupied by an emission.

(c) Station authorization.

A. (a) The authorized bandwidth is the maximum width of the band of frequencies, as specified in the authorizations, to be occupied by an emission.

(b) The bandwidth occupied by an emission is the width of the frequency band (normally specified in kilocycles) containing those frequencies upon which a total of 99 percent of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 percent of the total radiated power.

(c) A "station authorization" is any construction permit, license, or special temporary authorization issued by the Commission. The application for the permit or license must be signed by the applicant.

Q. 259. May stations in the Public Safety Radio Services be operated for short periods of time without a station authorization issued by the Commission? 21.

A. No. No radio transmitter shall be operated in the Public Safety Radio Services except under and in accordance with a proper station authorization granted by the Commission.

Q. 260. What notification must be forwarded to the Engineer-in-Charge of the Commission's district office prior to testing a new transmitter in the Public Safety Radio Service which has been obtained under a construction permit issued by the Commission. 21.

A. The permittee must notify the Engineer-in-Charge of the local radio district, giving him the following information: the date on which the transmitter will just be tested in such a manner as to produce radiation, the name of the permittee, the station location, the call sign and the frequencies on which tests are to be conducted. This notification must be made in writing at least two days in advance of the test date.

Q. 261. Where may standard forms applicable to the Public Safety Radio Services be obtained? 21.

A. Standard numbered forms applicable to the Public Safety Radio Services may be obtained from the Washington, D. C. 20554 office of the Federal Communications Commission, or from any of its engineering field offices.

Q. 262. In general, what type of changes in authorized stations must be approved by the Commission? What type does not require Commission approval? 21.

A. Proposed changes which will result in operations inconsistent with any of the terms of the current authorization require that an application for modification of construction permit and/or license be submitted to the Commission.

Proposed changes which will not depart from any of the terms of the outstanding authorization for the station involved, may be made without prior Commission approval. Such changes include the substitution of equivalent equipment provided the equipment to be installed is on the Commission's approved list.

Q. 263. The carrier frequency of a transmitter in the Public Safety Radio Service must be maintained within what percentage of the licensed value? Assume the station is operating at 160 Mc. with a licensed power of 50 watts. 21.

A. 0.0005 percent. The following table indicates the percentage variation permitted in the Public Safety Radio Services.

Frequency Range	All Fixed and Base Stations Percent	ALL MOBILE STATIONS Over 3 Watts Percent	3 Watts or Less Percent
Below 25 Mc.	.01	.01	.02
25 to 50 Mc.	.002	.002	.005
50 to 1000 Mc.	.0005*	.0005	.005

* Transmitters authorized for operation on or before Dec. 1, 1961, in the frequency band 73.0 - 74.6 Mc. may operate with a frequency tolerance of .005 percent.

Q. 264. What is the authorized bandwidth and frequency deviation of Public Safety stations operating at about 30 Mc.? at about 160 Mc.? 21.

A. At 30 Mc. the maximum authorized bandwidth and frequency deviation are 20 Kc. and 5 Kc. respectively. It is the same at 160 Mc. This is taken from the following table which shows the maximum authorized bandwidth and maximum authorized frequency deviation for all F3 emission.

Frequency Band	Authorized bandwidth	Frequency deviation
25 to 50 Mc.	20 Kc.	± 5 Kc.
50 to 150 Mc.	20 Kc.	± 5 Kc. *
150 to 450 Mc.	20 Kc.	± 5 Kc.
450 to 1000 Mc.	40 Kc.	± 15 Kc.

* Transmitters authorized for operation on or before May 1, 1964, have until Nov. 1, 1964, to meet this requirement. Transmitters authorized for operation on or before Dec. 1, 1961, in the frequency band 73.0 - 74.6 Mc. may continue to operate with a bandwidth of 40 Kc. and a deviation of ± 15 Kc.

Q. 265. What is the maximum percentage modulation allowed by the Commission's Rules for stations in the Public Safety Radio Services which utilize amplitude modulation. 21.

A. The modulation percentage must be sufficient to provide efficient communication and normally shall be maintained above 70% on peaks, but must not exceed 100% on negative peaks.

Q. 266. Define "control point" as the term refers to transmitters in the Public Safety Radio Service. 21.

A. A "control point" is an operating position which meets all of the following conditions:

(1) The position must be under the control and supervision of the licensee;
(2) It is a position at which the monitoring facilities required by this section are installed; and
(3) It is a position at which a person immediately responsible for the operation of the transmitter is stationed.

21.

Q. 267. Outline the transmitter measurements required by the Commission's Rules for stations in the Public Safety Radio Service.

A. The licensee of each station, having a transmitter with a plate power input to the final stage in excess of three watts, must employ suitable procedures to determine the following:

(1) That the carrier frequency is maintained within its prescribed tolerance;
(2) That the plate power input to the final RF stage does not exceed the maximum figure specified on the current station authorization. Where the transmitter is so constructed that a direct measurement of plate current in the final radio frequency stage is not practicable, the plate input power may be determined from a measurement of the cathode current in the final radio frequency stage.
(3) That the modulation of the transmitter does not exceed the specified limits.

The measurements to determine the above must be made:

(1) When the transmitter is first installed.
(2) When any change is made in the transmitter which may affect the above measurements.
(3) At intervals not to exceed one year.

For transmitters not using crystal-controlled oscillators, carrier frequency measurements must be made at intervals not to exceed one month.

Q. 268. What are the general requirements for transmitting the identification announcements for stations in the Public Safety Radio Service? 21.

A. Each station in these services shall transmit the required identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period.

A mobile station, authorized to the licensee of the associated base station and which transmits only on the transmitting frequency of the associated base station, is not required to transmit any identification.

Q. 269. When a radio operator makes transmitter measurements required by the Commission's Rules for a station in the Public Safety Radio Service, what information should be transcribed into the station's records? 21.

A. Where service or maintenance duties are performed, the responsible operator shall sign and date an entry in the station record giving:

(1) Pertinent details of all duties performed.
(2) His name and address.
(3) The class, serial number and expiration date of his license.

Q. 270. What are the Commission's general requirements regarding the records which are required to be kept by stations in the Public Safety Radio Service? 21.

A. The records must be kept in an orderly manner and in such detail that the data required are readily available. Each entry must be signed by a person qualified to do so and having actual knowledge of the facts to be recorded. There are to be no erasures. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made and indicate the date of the correction.

Q. 271. Describe the various methods by which a standard broadcast station may compute its operating power. 21.

A. In general, the operating power of each station shall be determined by DIRECT measurement of the antenna power. This is done by multiplying the square of the antenna current by the antenna resistance at the point where the current is measured.

A second method of determining operating power is the INDIRECT method. In this method, we find the operating power by multiplying the final tube's plate voltage by the final tube's total plate current by a factor, F. The factor F, which is found in FCC tables, depends upon the type of modulation and power used.

FCC-TYPE EXAMINATION

ELEMENT 3

1. The basic unit of current is the:
   a. volt b. farad c. ampere d. ohm

2. In a conductor, the free electrons:
   a. are tightly bound to their atoms.
   b. are in the outer orbits and not tightly bound to their atoms.
   c. must be neutralized before they can flow.
   d. must have their electrostatic fields in one direction.

3. Assuming a source of 100 V DC, what resistance must be placed in series with a 600 ohm relay if we wish to have 0.1 ampere flow through it.
   a. 400 ohms b. 1000 ohms c. 600 ohms d. 1600 ohms

4. Skin effect refers to:
   a. corona discharge at the surface of a conductor.
   b. resistance to RF current flow at the center of the conductor.
   c. resistance to AF current flow at the surface of the conductor.
   d. physical shortening of antenna to obtain resonance.

5. What is the value of a resistor that is color coded red, green and black?
   a. 35 ohms b. 250 ohms c. 240 ohms d. 25 ohms

6. Increasing the Q of a tuned circuit will:
   a. increase its bandwidth c. decrease its gain
   b. decrease its reactance d. decrease its bandwidth

7. The impedance of a series resonant circuit containing no resistance is:
   a. infinite c. equal to that of a parallel resonant circuit.
   b. zero d. one-half that of a parallel resonant circuit.

8. What would not happen if the field of a shunt wound DC motor would open while the machine is running under no load?
   a. the speed of the motor would increase.
   b. the armature current would increase.
   c. the motor could burn out.
   d. the counter-emf in the armature would increase.

9. The power factor is the:
   a. wattmeter reading divided by the apparent power.
   b. volt-amperes divided by the true power.
   c. apparent power divided by the true power.
   d. current squared, multiplied by the resistance.

10. Impedance matching is primarily necessary for:
   a. miniaturization of equipment
   b. economy of design
   c. reduction of harmonic transfer
   d. maximum transfer of power

11. Which of the following will not cause the plates of a rectifier to suddenly become red hot?
   a. a shorted filter capacitor
   b. a shorted filter choke
   c. a short between B+ and ground
   d. a short between the filter choke and ground

12. The life of a vacuum tube will not be shortened by:
   a. excessive screen current
   b. insufficient filament voltage
   c. excessive plate voltage
   d. insufficient grid bias

13. The principal advantage of a tetrode over a triode is:
   a. more power can be had
   b. more voltage gain can be had
   c. neutralization is not required
   d. distortion is considerably reduced

14. A cathode ray oscilloscope uses a sawtooth oscillator in its:
   a. horizontal deflection circuit
   b. damping circuit
   c. brightness circuit
   d. low voltage power supply

15. As compared to a Class A amplifier, a Class C amplifier:
   a. has less distortion
   b. requires less driving power
   c. operates over the linear portion of its characteristic curve
   d. operates over a greater part of its characteristic curve

16. Motorboating in an audio amplifier having a single power supply can be prevented by:
   a. de-coupling resistors and capacitors
   b. reducing the filter capacitor values
   c. increasing the screen voltage
   d. reducing the plate and screen voltages

17. Removing the cathode by-pass capacitor in an audio stage will:
   a. increase distortion
   b. decrease distortion
   c. increase gain
   d. none of the above

18. Which of the following is not used in neutralizing an RF amplifier:
    a. remove B+ from stage to be neutralized
    b. tuned circuits should be made resonant to incoming signal
    c. tune up preceding stage
    d. neutralizing condensers should be adjusted for maximum indication.

19. Harmonics in transmitters are not minimized by:
    a. use of a Faraday shield
    b. increased final stage grid bias
    c. reduced power levels of stages preceding the final
    d. use of by-pass capacitors with low lead inductances

20. What is the bandwidth of emission in AM transmission if a 2 Mc. carrier is modulated by audio whose highest frequency is 4,000 cycles?
    a. 2.004 Mc. b. 4.008 Mc. c. 8 Kc. d. 4 Kc.

21. The phase relationship between the input and output signals of a common base transistor amplifier is:
    a. 180° out of phase. b. 90° out of phase
    c. the input and output signals are in phase.
    d. the phase relationship varies according to the transistor used.

22. Grid modulation as compared to plate modulation:
    a. requires less audio power c. produces less distortion
    b. produces greater linearity d. is easier to adjust

23. Frequency shift is caused by:
    a. poor voltage regulation c. overmodulation
    b. high plate and screen voltages d. inadequate by-passing

24. What is the image frequency in a superheterodyne if the incoming signal is 104 Mc. and the local oscillator frequency is 114.7 Mc.?
    a. 93.3 Mc. b. 10.7 Mc. c. 21.4 Mc. d. 125.4 Mc.

25. A tube can act as a variable inductance in a:
    a. reactance tube modulator c. Foster-Seeley discriminator
    b. ratio detector d. Heterodyne Frequency meter

26. The modulator index is equal to:
    a. twice the highest modulating frequency
    b. the carrier frequency deviation divided by the modulating frequency
    c. the carrier frequency deviation divided by the deviation ratio
    d. the deviation ratio divided by the carrier frequency deviation

27. In aligning a Foster-Seeley Discriminator:
    a. two equal resistors are added to the output
    b. the primary of the discriminator transformer is adjusted for minimum output
    c. the secondary of the discriminator transformer is adjusted for minimum output
    d. the meter is placed between the center of the output resistors and the primary of the discriminator transformer

28. In semiconductor conduction, a "flow of holes" refers to:
    a. a flow of positive carriers
    b. a flow of electrons
    c. a flow of protons
    d. a flow of neutrons

29. A "thermistor" is used to:
    a. keep the temperature around a crystal constant
    b. stabilize a transistor amplifier
    c. aid in voltage regulation
    d. reduce the reverse base-to-emitter current

30. What is the efficiency of an amplifier stage having a plate voltage of 600 volts, a plate current of 120 ma. and an output power of 50 watts?
    a. 50% b. 60% c. 144% d. 70%

31. How much power is entering a transmitting antenna if the antenna ammeter reads 1.4 amperes at a 52 ohm point?
    a. 72.8 watts
    b. 101.92 watts
    c. 37.1 watts
    d. 43.4 watts

32. A 1/4 wave vertical antenna radiates well:
    a. in all horizontal directions
    b. in all vertical directions
    c. in all directions except towards earth
    d. none of the above

33. The fully charged voltage of a lead acid cell is:
    a. 2.1 V. b. 6.3 V. c. 1.5 V. d. 12.6 V.

34. Stub-tuning does not:
    a. eliminate undesirable radiation
    b. eliminate standing waves
    c. match impedances
    d. filter out harmonics

35. A Heterodyne Frequency meter does not contain a:
    a. crystal oscillator and harmonic amplifier
    b. variable frequency oscillator
    c. mixer
    d. ratio detector

36. Diversity reception is used to:
    a. reduce distortion
    b. reduce harmonic reception
    c. reduce fading
    d. reduce interference

37. Sulphation does not cause:
    a. high internal I^2R losses
    b. buckling of plates
    c. excessive heating
    d. increase in cell's capacity

38. The electrolyte of a lead-acid cell contains:
    a. hydrochloride acid
    b. lead dioxide
    c. sulphuric acid
    d. ammonium sulphate

39. The speed of a DC series motor is determined mainly by:
    a. its load
    b. its field strength
    c. its voltage
    d. its line frequency

40. Excessive sparking at the brushes of a DC motor is caused by:
    a. RF feedback
    b. brushes in neutral position
    c. motor underload
    d. dirty commutator

41. If we reduce the cross-sectional area of a 5 ohm piece of copper wire to one-fifth of its original size, the new resistance will be:
    a. 1 ohm b. 1/5 of an ohm c. 25 ohms d. 125 ohms

42. The frequency of a crystal oscillator is determined chiefly by:
    a. the temperature at the plate coil.
    b. the capacity of the tube.
    c. the thickness of the crystal.
    d. the LC ratio of the plate tank circuit.

43. "Type approval" when applied to equipment, indicates that:
    a. the manufacturer has submitted data concerning the equipment
    b. the FCC has conducted tests on the equipment.
    c. the licensee has submitted data concerning the equipment.
    d. none of the above.

44. Stations in the Public Safety Radio Services may be operated without a station authorization for a period:
    a. not to exceed 3 months
    b. not to exceed 30 days
    c. not to exceed 48 hours
    d. none of the above

45. Which of the following designations indicates frequency modulated television?
    a. F5 b. A3 c. F3 d. P3D

46. The maximum authorized bandwidth of Public Safety stations operating between 25 and 50 Mc. is:
    a. 20 kc. b. 10 kc. c. 30 kc. d. 5 kc.

47. The principal function of a swinging choke in a filter system is:
    a. to improve regulation of the power supply under varying loads
    b. to provide pure, constant AC input to the power supply.
    c. to prevent harmonic radiation.
    d. to cause air circulation around the rectifiers.

48. The effective value of a sine wave is:
    a. twice its peak value
    b. .0707 of its peak value
    c. .4443 of its peak value
    d. .707 of its peak value

49. Resistors are sometimes connected in series with the grids of a transmitter's RF amplifier tubes in order to:
    a. increase the efficiency of the stage.
    b. eliminate odd order harmonics.
    c. broaden the response of the grid tuned circuit.
    d. reduce parasitic oscillations.

50. A buffer amplifier is used to:
    a. improve the efficiency of an RF thermocouple.
    b. decrease the amplifier output.
    c. raise the Q of the oscillator.
    d. improve the frequency stability of the oscillator stage.

51. In a Class C vacuum tube amplifier, efficiency may run as high as:
    a. 85% b. 100% c. 50% d. 200%

52. Adding parasitic elements to an antenna will:
    a. increase its efficiency
    b. increase its capacitance
    c. decrease its inductance
    d. increase its directivity

53. In order to improve the frequency stability of an oscillator:
    a. temperature changes are introduced by means of blowers.
    b. a buffer stage should not be used.
    c. a high capacity to inductance ratio is employed.
    d. a high inductance to capacity ratio is employed.

54. Which of the following oscillators uses the tube's interelectrode capacitance for feedback?
    a. Hartley b. Colpitts c. Armstrong d. T.P.T.G.

55. A doubler amplifier stage:
    a. doubles the power output.
    b. doubles the fundamental frequency.
    c. doubles the inductance of the amplifier.
    d. doubles the load on the amplifier.

56. Voltage regulation in conventional power supplies is improved by:
    a. proper fusing
    b. a "bleeder" resistance
    c. a filter condenser
    d. high-resistance filter chokes

57. The VHF range extends from:
    a. 300 to 3,000 kc.
    b. 3,000 to 30,000 kc.
    c. 30,000 kc. to 300 Mc.
    d. 300 to 3,000 Mc.

58. SHF (super high frequency) refers to the frequency range between:
    a. 300,000 Mc. and 300,000,000 Mc.
    b. 30,000 kc. and 3,000 Mc.
    c. 3,000 Mc. and 30,000 Mc.
    d. 3,000 Mc. and 30,000 kc.

59. What is the wavelength of a 350 Mc. signal?
    a. 1.17 meters
    b. 1,170 meters
    c. 86 centimeters
    d. 300 meters

60. In an FM radio communication system, "deviation ratio" refers to:
    a. the standard deviation of the various components.
    b. the deviation from accepted modulation practices.
    c. the ratio of the maximum permissible frequency deviation to the maximum permissible audio modulating frequency.
    d. the ratio of deviation between power input and power output.

61. The ratio of the audio power to the input power of the final stage in 100% sinusoidal plate modulation is:
    a. 25% b. 30% c. 50% d. 100%

62. Insulators are placed in antenna guy wires:
    a. to increase the inherent strength of the wires.
    b. to prevent transmitter over-loading.
    c. to reduce the efficiency of the wires to act as radiators.
    d. to increase RF losses in the guy wires.

63. The purpose of a "squelch" circuit is to:
    a. reduce the signal strength of the incoming signal.
    b. render the receiver inoperative when no carrier wave is present.
    c. increase the strength of all incoming signals.
    d. turn off the transmitter when safe voltage is not maintained.

64. A land station in the land mobile service carrying on a service with land mobile stations is called a:
    a. land station
    b. base station
    c. fixed station
    d. land mobile station

65. The following does not aid in eliminating receiver interference:
    a. a suitable noise limiter
    b. a crystal filter
    c. horizontally polarized antennas
    d. elimination of all shielding

66. What happens if C2 of Figure 86B1 opens up?
    a. the voltage across R_g drops.
    b. the voltage across C_c increases.
    c. the plate current drops.
    d. the RF voltage across L_2 increases.

67. Radio-frequency chokes are sometimes placed in the power leads between a motor generator power supply and a high-powered radio transmitter in order to:
    a. increase the transmitter output
    b. reduce the effect of high voltage kick-back on the high voltage generator, and to reduce RF interference caused by commutator sparks
    c. provide a safe means for regulating the output of the generator
    d. decrease the output of the high voltage generator when not in use

68. The principal disadvantage of crystal-controlled oscillators is:
    a. frequency instability more pronounced
    b. high voltage requirements
    c. insufficient "drive" to the final
    d. difficulty in changing operating frequencies

69. In a Class C amplifier, current flows approximately:
    a. 1/3 of the time
    b. 1/2 of the time
    c. 3/4 of the time
    d. all of the time

70. The temperature of a quartz crystal should:
    a. vary according to the power input
    b. be kept constant
    c. not be kept constant for considerable lengths of time
    d. be kept as low as possible

71. The percentage regulation of a power supply with a no-load voltage output of 126.5 volts and a full-load voltage output of 115 volts is:
    a. approximately 93% b. 10% c. 126.5% d. 110%

72. Adding an inductor in series with an antenna would:
    a. reduce the resonant frequency of the antenna
    b. increase the resonant frequency of the antenna
    c. be similar to shortening the antenna
    d. not affect the antenna's resonant frequency

73. When using grid leak bias only, the loss of radio frequency excitation to a Class "C" modulated amplifier would result in:
    a. excessive grid bias
    b. excessive plate current due to zero bias
    c. insufficient plate current
    d. an increase in the percentage of modulation

74. An advantage of push-pull operation is:
    a. increased power output
    b. complete DC core saturation
    c. creation of even-harmonic distortion
    d. production of regenerative feedback

75. A high percentage of modulation would result in:
    a. greater signal loss.
    b. less useful transmitted power for a given carrier power.
    c. a lower signal to noise ratio at the receiver.
    d. a higher signal to noise ratio at the receiver.

76. The center-tap connection on a filament transformer:
    a. increases the transformer's output.
    b. prevents hum voltages from modulating the signal.
    c. lowers the output of the transformer.
    d. produces radical changes in bias.

77. The ratio of current to voltage in a circuit is known as:
    a. inductance b. capacitance c. conductance d. impedance

78. The advantages of a mercury-vapor rectifier over a high-vacuum type rectifier do not include:
    a. greater efficiency and economy
    b. cooler operation
    c. better filament efficiency
    d. high internal drop of voltage

79. One form of wasted energy that occurs in the iron core of a transformer is called:
    a. residual magnetism
    b. Eddy currents
    c. copper losses
    d. corona discharge

80. The position of an antenna with respect to the surface of the earth:
    a. does not affect the emitted wave.
    b. determines the polarization of the emitted wave.
    c. affects the efficiency of RF transmitters.
    d. does not affect a received signal.

81. An AM system:
    a. requires critical receiving antenna specifications at broadcast frequencies.
    b. requires more complicated transmitter circuits than does an FM system.
    c. does not have the stability of an FM system.
    d. requires less bandwidth than does an FM system.

82. Which of the following would be used to transmit extremely high frequencies?
    a. magnetron b. klystron c. traveling wave tube d. waveguide

83. A problem that can arise with long horizontal waveguides is:
    a. moisture accumulation.
    b. reduction of Q.
    c. increased inductance.
    d. increased capacitance.

84. The time it takes for a capacitor to charge up to 63% of its final voltage is called:
    a. time factor b. time constant c. reluctance d. admittance

85. A tube that contains two triodes within a single glass envelope is called a:
    a. dual-tube
    b. duo-triode
    c. parallel tube
    d. push-pull triode

86. The alpha cutoff frequency is primarily dependent upon the:
    a. emitter current.
    b. collector-to-base voltage.
    c. physical thickness of the base.
    d. material makeup of the collector.

87. A dip in the antenna current in a plate modulated RF amplifier is not caused by:
    a. low-grid bias
    b. inadequate excitation
    c. incorrect load impedance
    d. insufficient modulation

88. What would happen if the coupling capacitor of Figure 123B became leaky?
    a. the buffer plate current would decrease.
    b. the oscillator plate current increases.
    c. the voltage across the coupling capacitor increases.
    d. the buffer plate current would increase.

89. A grounded grid amplifier requires:
    a. plate neutralization
    b. grid neutralization
    c. cross neutralization
    d. none of the above

90. A characteristic of the carbon button microphone is:
    a. high sensitivity.
    b. wide frequency response.
    c. can withstand temperature extremes.
    d. non-sensitivity to vibration and handling.

91. Excessive feedback in a crystal oscillator may result in:
    a. a cracked crystal
    b. loss of neutralization
    c. reduced output
    d. tube cut-off

92. What is the gain of a stage having a triode with a mu of 20, a plate resistance of 4,000 ohms, a load impedance of 8,000 ohms and a plate voltage of 250 V?
    a. 18.4 b. 10.6 c. 13.3 d. 20

93. Assume a DC circuit consisting of a 100 V source, a 250 ohm resistor across the source, and a 50 ohm resistor and 35 watt, 111 volt lamp in series across the 250 ohm resistor; find the voltage across the 50 ohm resistor.
    a. 100 V. b. 7.5 V. c. 12.5 V. d. 20 V.

94. In the above problem, find the total current:
    a. 0.4A b. 0.65A c. 1.25A d. 0.15A

95. A good high frequency insulator is:
a. rubber b. bakelite c. mica d. glass

96. Draw a schematic diagram of a bridge rectifier circuit connected to a capacitor input filter.

97. Draw a schematic diagram of a vacuum tube electron-coupled oscillator.

98. Draw a schematic diagram of a push-push amplifier.

99. Draw a schematic diagram of an FM discriminator stage.

100. Draw a circuit diagram of the diode detector and first audio amplifier in a superheterodyne.

ANSWERS TO
FCC-TYPE EXAMINATION
ELEMENT 3

1. c	26. b	51. a	76. b
2. b	27. c	52. d	77. c
3. a	28. a	53. c	78. d
4. b	29. b	54. d	79. b
5. d	30. d	55. b	80. b
6. d	31. b	56. b	81. d
7. b	32. a	57. c	82. d
8. d	33. a	58. c	83. a
9. a	34. d	59. c	84. b
10. d	35. d	60. c	85. b
11. b	36. c	61. c	86. c
12. b	37. d	62. c	87. d
13. c	38. c	63. b	88. d
14. a	39. a	64. b	89. d
15. d	40. d	65. d	90. a
16. a	41. c	66. a	91. a
17. b	42. c	67. b	92. c
18. d	43. b	68. d	93. c
19. b	44. d	69. a	94. b
20. c	45. a	70. b	95. c
21. c	46. a	71. b	96. See A. 65D
22. a	47. a	72. a	97. See A. 86E
23. a	48. d	73. b	98. See A. 129
24. d	49. d	74. a	99. See A. 177D
25. a	50. d	75. d	100. See A. 157A

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